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Public Health Service ● Environmental Health Service

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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g=2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie=2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 5, May 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Radiological Health

Reports

Cesium-137 Concentrations in Eskimos, Spring 1968

J. A. Eckert[1], *J. S. Coogan*[1], *R. L. Mikkelsen*[2], and *P. N. Lem*[1]

To determine cesium–137 concentrations, 996 residents of 11 Alaskan villages were whole-body counted during April 1968. The methods of counting and selection of villages were chosen to complement the spring 1967 counts made by Rechen et al. The villages counted in this study were Ambler, Anaktuvuk Pass Village, Egegik, Kiana, Mekoryuk, Noatak, Noorvik, Selawik, Shishmaref, Shungnak, and Teller.

The maximum and average concentrations, considering all villages, were 24.27 nCi/kg and 4.37 nCi/kg, respectively. The average radiation dose index was 34.1 mrad/a. A comparison of the radiation dose indices of individuals counted both in the spring of 1967 and the spring of 1968 indicates that in two villages out of ten there was a significant decrease in the indices.

The inhabitants of villages living on a diet of caribou or moose meat had a higher cesium–137 burden than the inhabitants of villages where reindeer herds supply the main meat source.

The calibration formulas of Rechen and Palmer are compared and it is concluded that earlier studies made by Hanson and Palmer are compatible with the more recent studies made by the U.S. Public Health Service.

The Bureau of Radiological Health (BRH) instituted a surveillance program on the Alaskan native population in 1965 and is continuing this program at the present time (*1–3*). Bureau of Radiological Health participation followed earlier studies by Hanson and Palmer whose published results demonstrated a simple portable counting technique, the magnitude of the burdens in the areas counted, and some seasonal dependence (*4–6*). The results of the BRH whole-body counting for cesium-137 in the spring of 1967 determined the geographical distribution of the cesium-137 burdens, determined the burdens to a very large population (1,344 persons), and indicated that there was little dependency between cesium-137 burdens in village children and their participation in the Bureau of Indian Affairs school lunch program.

[1] Southwestern Radiological Health Laboratory, Bureau of Radiological Health, Las Vegas, Nev.

[2] Formerly, a Bureau of Radiological Health State assignee to the Alaska State Health Department, now with the Anchorage Borough Health Department, Anchorage, Alaska.

The overall objective of the spring 1968 survey was to continue surveillance of the cesium-137 levels. Of particular interest was the measurement of individuals who had been counted during the previous year for a direct comparison of the change in levels. Three villages, Barrow, Point Hope, and Wainwright, were dropped from the counting schedule because of the low levels found during the 1967 surveillance program. One village, Kiana, was added because the geographical location suggested high levels might be detected. The counting equipment and methods used were to be as nearly the same as possible to those used in the 1967 surveillance program to insure the validity of a direct comparison of results.

A rather extensive background on the reasons for this surveillance program can be found in Rechen et al (*1*). The counting procedure and equipment are essentially as described in the Rechen report. Individuals to be counted are seated and bent over the unshielded NaI crystal which is placed on their thighs. However, several exceptions were made in the equipment or meth-

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ods in the interest of greater performance reliability in the field. Integrated 7.5- by 7.5-cm NaI crystal-photomultiplier assemblies were used and printed paper-tape output was selected. This output required more effort for data analysis but provided much greater reliability in the field than punched paper tape.

Four detectors were used simultaneously on four subjects to enable rapid counting of residents. Almost without exception, 4-minute counting times were used. This combination of multiple detectors and counting times enabled the investigators to count an entire village usually in 1 day.

All counts were analyzed using computer techniques. The data were analyzed by selecting the half full width at maximum (FWHM) of the cesium-137 photopeak after subtraction of a relevant background and summing all counts under the photopeak over the resultant energy range. This particular area under the photopeak was chosen to minimize errors due to gain shifts or differences in resolution between crystals. The calibration formula was identical to that used by Rechen (*1*) in 1967, except that a factor of 0.75 was introduced to compensate for the summation of the smaller area. The Rechen formula is $nCi/CPM = 0.012\ (W)^{0.7}$. The calibration formula used in this study was:

$$\frac{nCi}{CPM} = 0.016\ (W)^{0.7}$$

where, nCi = total cesium-137 activity; (see Rechen et al.) (*1*);
W = body weight in kilograms;
CPM = counts per minute under photopeak limited by FWHM.

After calculating the burden using the above formula, a constant was added to the result to adjust for the burden of the background subject.

Background measurements in the villages were obtained by counting two of the investigators whose burdens had been determined by a large crystal whole body counter before and after the survey to insure the validity of the background burden. Dietary precautions were also taken by these individuals so as to minimize the uptake of cesium-137 during the period of the survey.

The results are also expressed in terms of the Radiation Dose Index (r_i). This parameter represents an estimate of the accumulative dose to the individual for 1 year if the body burden of cesium-137 were to be maintained at the same level for the year. A detailed discussion of this parameter can be found in the report of Rechen (*1*), and will not be duplicated here beyond a simple statement of the formula:

$$r_i = \left(W^{0.3} + 4.5\ \frac{nCi}{W} \right)$$

where, r_i = estimated total body dose in mrad/a;
W = body weight in kg; and
nCi = total cesium-137 concentration in nCi.

A Radiation Dose Index was computed for each individual rather than for population groups as per the Rechen report (*1*). Thus, data on population groups were obtained by averaging the individual indices.

Although Rechen (*1*) and Palmer (*4*) used the same counting method and calibration techniques, their respective calibration formulae were quite different. In figure 1 both formulae have been plotted, equating the two curves at a body weight of 70 kg. Note that both formulae yield the same results over an extended range of body weights. An attempt was made to verify the calibration formulae using residents of Nevada with inherently low body burdens of cesium-137. The body burdens were determined using large crystal (11- by 4 inch) whole-body counting techniques. The large crystal whole-body counting facility used was that operated by the Southwestern Radiological Health Laboratory in Las Vegas, Nev. Calibra-

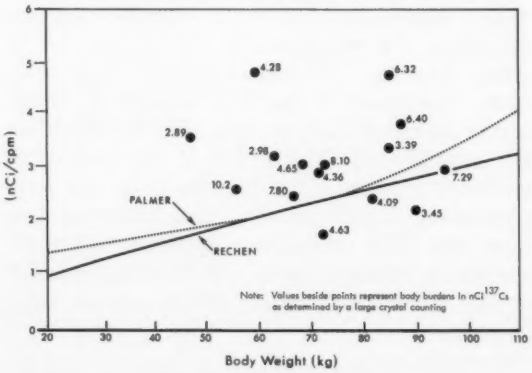

Figure 1. Comparison of calibration formula and whole body results
(Values beside points represent cesium-137 body burdens in nCi of Nevada residents as determined with a large crystal)

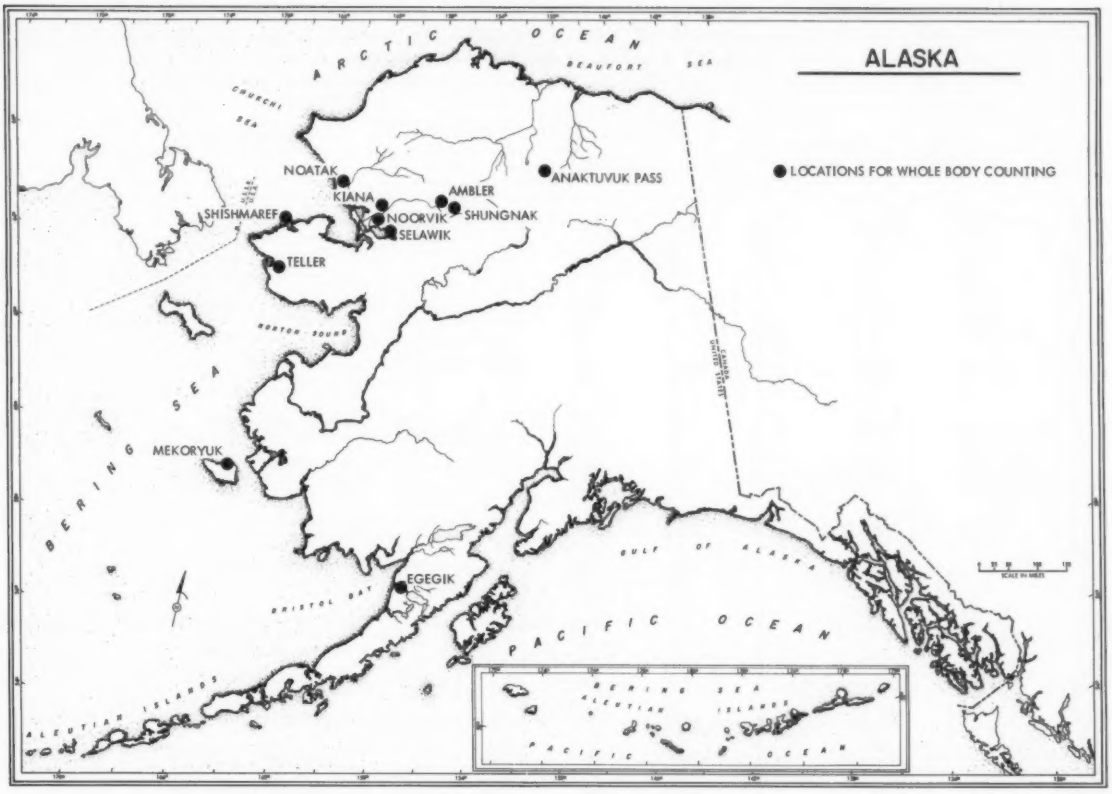

Figure 2. Alaskan locations for whole body counting, April 1968

tion was performed using a phantom constructed of cesium-137 spiked sugar bags. Immediately after being counted with the large crystal, the Nevada residents were counted using the "lap" technique, but in a large shielded enclosure rather than an unshielded room as experienced under field conditions. The values of the cesium-137 burdens in nCi, as determined using the large crystal, are plotted with the Rechen-Palmer curves in figure 2.

Dietary studies of Alaskan villages show that a large percentage of protein intake is obtained from local supplies. Data are available in current literature on three of the villages counted, Noatak, Shishmaref, and Shungnak, where the percentage of consumed protein from locally obtained food is 75 percent, 78 percent, and 81 percent, respectively (7). Individual dietary information was not collected, but rather, an overall view of food consumption in a village was obtained through interviews with village leaders. This information, as well as population information, is listed in table 1. The locations are noted in figure 2. In the population figures, the designation "High School Students" in all cases refers to students temporarily living at Bureau of Indian Affairs schools located away from the village.

Counting results and conclusions

Table 2 lists the average and maximum concentrations of cesium-137 in individuals and the average and maximum Radiation Dose Indices. The tabulation is by village, sex, and weight classification. Also listed are the counting dates, number of individuals counted, average height and average weight. Table 2 also includes summary information on all villages. The maximum recorded burden was 24.27 nCi/kg in a 52-year-old male living in Selawik. This individual weighed 69 kg giving a total burden of 1.7μCi. The Radiation Dose Index for this individual (also the highest value) was 195.7 mrad/a. The applicable

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Table 1. Population and diet parameters

Date (1968)	Location	Population				Native diet
		Total[a]	Students[a]	High school students[a,b]	Adults above 16 years[a]	
4/6	Noatak	210	82	20–25	Unknown	Caribou plentiful all winter Seven moose killed in village Four bear Some Dolly Varden Trout and Shee fish taken all winter.
4/8	Noorvik	450	138	50	Unknown	Caribou far away from village; not plentiful Shee fish in good supply
4/9	Kiana	250	90	20–22	Unknown	Caribou, plentiful Moose, plentiful; Shee fish, catch beginning at this date
4/10	Ambler	140	44	10	Male 24 Female 31	Caribou in good supply Some Shee fish
4/11	Shungnak	176	54	19	Unknown	Caribou kill, light Most families killed a moose Some fishing
4/14	Selawick	430	130	50	Male 112 Female 100	Caribou and moose kill, good White fish—pickerel
4/16	Shishmaref	261	70	23	Male 62 Female 54	Walrus, seal, reindeer herd controlled by native herder Some fish
4/17	Teller	180	52	Unknown	Unknown	Reindeer herd controlled by native herder, some fish Mostly store-bought food
4/20	Anaktuvuk Pass	125	51	6	Unknown	Caribou supply, excellent (main stable of diet)
4/21	Egegik	180–200	59	10	Unknown	Caribou kill, excellent Fish Store-bought food constitutes a large portion of diet
4/22	Mekoryuk, Nunivak Island	325	95	20	Unknown	Main dietary components: BIA reindeer herd on island, duck, seal, a few walrus.

[a] Students, high school students and adults above 16 years are included in the total population.
[b] Students temporarily living at Bureau of Indian Affairs Schools located away from the village.

FRC Radiation Protection Guide is 500 mrad/a. A comparison of males and females of the same weight range and residing in the same village revealed that differences by sex in cesium-137 burdens is only important in the higher weight ranges, thus verifying the conclusion reached by Rechen. Males in the higher weight range have significantly higher burdens than females.

Table 3 presents a comparison of the results of the spring 1967 and spring 1968 whole-body counts. Data on the spring 1967 counts were taken from the Rechen report (*1*) and the data for 1966 were from Fitzpatrick (*3*). It should be noted that the Radiation Dose Indices for 1968 were based on averages of the individual radiation dose indices whereas the 1967 indices were based on group averages. The villages were counted in the spring of both years, thus, hopefully eliminating any seasonal dependence. In 43 of the 60 categories compared, the 1967 concentrations were higher.

Figure 3 shows a bar graph of the Radiation Dose Index for a particular category of males, 45–65 kg. A comparison of this graph and the dietary information listed in table 1 demonstrates that in general (Noatak being the exception) individuals in those villages relying on caribou and moose have higher cesium-137 burdens than those with reindeer herds. The villages with the highest concentrations (Ambler, Kiana, Noorvik, Selawik, and Shungnak) are located in the Kobuk River region. Investigations in the past have concentrated on caribou or reindeer as the principle link in the ecological chain responsible for the high cesium-137 burdens found in Arctic peoples. In Shungnak, where the burden was high (table 1) the residents were consuming primarily moose rather than caribou or reindeer. This would suggest the need to study the consumption of other native animals as possible sources of cesium-137.

Comparison of the calibration formulas of Rechen (*1*) and Palmer (*4*) showed very good

Table 2. Spring 1968 maximum cesium-137 concentrations and Radiation Dose Indices for Alaskan Eskimos by place of residence, sex, weight and height

Location and counting dates (1968)	Sex	Weight range (kg)	Number counted	Average height (cm)	Average weight (kg)	Cesium-137 concentrations		Radiological Dose Indices (mrad/a)	
						Maximum (nCi/kg)	Average (nCi/kg)	Maximum	Average
Ambler	Male	<45	13	137	31	15.29	8.73	106.9	63.6
4/10		46–65	6	167	54	21.86	11.68	174.8	91.4
		>65	6	172	85	14.68	6.89	118.1	56.8
	Female	<45	13	137	34	11.56	6.68	85.3	49.4
		46–65	18	158	56	14.94	7.47	116.9	58.8
		>65	7	161	76	6.88	4.41	55.5	36.1
Anaktuvuk Pass Village	Male	<45	13	128	31	4.84	3.23	36.4	23.6
4/20		46–65	3	157	54	7.48	4.61	59.7	36.3
		>65	10	169	71	9.27	6.67	74.4	54.0
	Female	<45	11	130	31	5.11	3.18	38.5	23.3
		46–65	13	153	55	9.26	5.12	72.1	40.0
		>65	2	155	70	4.93	4.42	39.6	35.7
Egegik	Male	<45	25	132	31	8.20	2.88	62.6	21.2
4/21–4/22		46–65	13	160	57	5.54	3.25	44.3	25.6
		>65	21	172	80	11.30	2.95	90.6	24.1
	Female	<45	21	130	30	6.74	3.02	47.6	21.9
		46–65	15	158	56	4.75	2.68	37.4	21.1
		>65	6	157	75	3.97	2.61	32.2	21.3
Kiana	Male	<45	16	145	37	4.78	2.28	35.9	17.0
4/9		46–65	12	160	56	7.32	3.50	58.3	27.6
		>65	21	172	76	8.56	4.56	70.9	37.2
	Female	<45	19	146	38	4.75	2.11	35.5	15.7
		46–65	25	156	56	5.49	2.94	43.5	23.1
		>65	14	160	75	5.30	2.79	42.8	22.7
Mekoryuk, Nunivak Island	Male	<45	31	135	34	6.93	3.62	51.1	26.7
4/22		46–65	12	161	58	7.10	3.72	56.8	27.9
		>65	9	166	73	3.65	2.45	29.5	19.9
	Female	<45	16	140	38	6.45	3.32	48.5	24.8
		46–65	28	153	55	5.69	3.05	45.1	23.9
		>65	10	157	77	5.16	2.72	42.0	22.2
Noatak	Male	<45	7	147	40	3.82	2.05	29.0	15.5
4/6		46–65	6	159	52	4.05	2.15	32.3	16.9
		>65	33	172	77	6.63	3.43	54.0	28.0
	Female	<45	7	137	36	3.44	1.73	26.0	13.0
		46–65	20	137	56	3.22	2.08	25.1	16.4
		>65	11	158	74	2.46	1.48	19.9	12.0
Noorvik	Male	<45	18	146	38	7.65	3.09	57.2	23.2
4/8		46–65	24	167	57	8.23	4.79	66.3	37.9
		>65	26	170	75	12.40	5.76	101.1	47.0
	Female	<45	11	143	39	5.05	3.51	38.2	26.3
		46–65	35	158	57	8.30	3.91	65.6	30.8
		>65	8	160	74	3.95	3.14	32.4	25.6
Selawik	Male	<45	28	131	32	15.14	7.07	112.5	51.6
4/14		46–65	20	161	57	13.86	7.54	110.9	59.4
		>65	24	167	74	24.27	10.53	195.7	85.6
	Female	<45	16	136	34	12.26	6.91	89.5	50.9
		46–65	21	153	57	14.85	7.05	117.3	55.4
		>65	7	159	81	6.31	5.57	51.5	45.9
Shishmaref	Male	<45	14	138	34	7.66	3.89	55.5	28.7
4/16		46–65	10	161	58	6.80	4.34	54.2	34.3
		>65	34	169	77	8.07	4.49	65.8	36.6
	Female	<45	16	141	36	4.40	2.88	30.8	21.4
		46–65	16	156	57	7.07	3.02	55.2	23.8
		>65	12	156	78	3.90	2.51	31.7	23.2
Shungnak	Male	<45	16	141	35	11.37	5.98	84.2	44.4
4/13		46–65	6	164	58	11.42	8.66	90.8	68.5
		>65	12	176	78	17.53	8.25	142.1	67.4
	Female	<45	9	139	34	8.31	4.80	62.9	35.4
		46–65	17	156	55	17.60	7.52	135.8	58.9
		>65	5	159	70	8.80	5.30	70.5	42.8
Teller	Male	<45	17	143	38	5.94	3.59	45.3	26.8
4/17		46–65	15	165	58	4.85	3.50	38.5	27.5
		>65	12	170	75	8.69	3.58	71.1	29.1
	Female	<45	15	140	36	4.11	2.11	29.7	15.7
		46–65	15	154	54	3.90	2.20	30.6	17.2
		>65	4	168	70	3.29	2.71	26.5	22.0
Total	Male	<45	198	138	35	15.29	4.32	112.5	31.8
4/6–4/22/68		46–65	127	162	56	21.86	5.01	174.8	39.6
		>65	208	170	76	24.27	5.27	195.7	43.0
	Female	<45	154	138	35	12.26	3.63	89.5	27.0
		46–65	223	156	56	17.60	4.19	135.8	33.0
		>65	86	159	75	8.80	3.12	70.5	25.5

Table 3. Comparison of 1966, 1967, and 1968 average and maximum concentrations of cesium-137 in Alaskan Eskimos by place of residence, sex, and weight

Location	Sex	Weight range (kg)	Number counted			Average weight (kg)			Ratio of maximum concentrations		Ratio of average concentrations	
			1966	1967	1968	1966	1967	1968	1967/1966	1968/1967	1967/1966	1968/1967
Ambler	Male	< 45		19	13		29	31		1.09		1.04
		46–65		9	6		58	54		1.29		1.17
		> 65		13	6		77	85		.70		.62
	Female	< 45		17	13		30	34		.83		.82
		46–65		20	18		57	56		.85		.82
		> 65		8	7		72	76		.94		.90
Anaktuvuk Pass Village	Male	< 45		4	13		34	31		.87		.82
		46–65	3	9	3	59	60	54	1.10	.40	.92	.52
		> 65	5	14	10	74	72	71	1.30	.55	.82	.79
	Female	< 45		4	11		37	31		.55		.55
		46–65		13	13		55	55		.91		.86
		> 65		2	2		73	70		.93		.90
Egegik	Male	< 45		25	25		31	31		1.15		1.28
		46–65	12	18	13	59	57	57	1.04	.39	.81	.77
		> 65	19	14	21	77	79	80	.90	1.57	1.03	1.05
	Female	< 45		15	21		28	30		.98		.95
		46–65		14	15		54	56		.58		1.18
		> 65		4	6		74	75		.60		.61
Mekoryuk, Nunivak Island	Male	< 45		13	31		32	34		1.72		1.47
		46–65		16	12		58	58		1.13		.76
		> 65		16	9		72	73		.47		.52
	Female	< 45		11	16		34	38		1.07		1.24
		46–65		22	28		57	55		1.18		1.05
		> 65		8	10		75	77		1.56		1.27
Noatak	Male	< 45		24	7		31	40		.64		.76
		46–65		13	6		59	52		.50		.52
		> 65		34	33		75	77		.71		.57
	Female	< 45		24	7		32	36		.68		.74
		46–65		23	20		56	56		.54		.58
		> 65		15	11		77	74		.55		.56
Noorvik	Male	< 45		23	18		35	38		.93		.56
		46–65	1	22	24	64	55	57	2.82	.46	1.32	.56
		> 65		35	26		73	75		.62		.52
	Female	< 45		10	11		35	39		.51		.58
		46–65		37	35		57	57		.57		.56
		> 65		15	8		75	74		.37		.72
Selawik	Male	< 45		33	28		30	32		.91		.87
		46–65	11	19	20	61	59	57	.79	.71	.65	.66
		> 65	22	15	24	73	76	74	.54	1.40	.56	1.08
	Female	< 45		45	16		28	34		.78		.88
		46–65		40	21		55	57		.81		.79
		> 65		14	7		78	81		.48		.74
Shishmaref	Male	< 45		22	14		30	34		1.09		1.11
		46–65		15	10		59	68		.62		.89
		> 65	1	25	34	77	77	77	1.82	.70	.74	.96
	Female	< 45		22	16		30	36		.64		.81
		46–65		28	16		54	57		1.15		.93
		> 65		10	12		77	78		.88		.79
Shungnak	Male	< 45		29	16		29	35		1.04		.95
		46–65		14	6		56	58		.86		1.01
		> 65		13	12		74	78		.97		.68
	Female	< 45		22	9		28	34		.77		.75
		46–65		23	17		55	55		1.41		1.14
		> 65		3	5		72	70		1.49		1.23
Teller	Male	< 45		14	17		32	38		1.51		1.72
		46–65		15	15		60	58		.77		.91
		> 65		9	12		75	75		1.24		.91
	Female	< 45		19	15		33	36		.94		1.19
		46–65		18	15		56	54		.63		.96
		> 65		6	4		74	70		.97		1.71
Total	Male	< 45		252	198		32	35		.92		1.09
		46–65	34	196	127	60	58	56	.79	1.13	.71	.96
		> 65	88	250	208	75	76	76	.54	1.16	.78	.93
	Female	< 45		231	154		32	35		.78		.92
		46–65		285	223		55	56		.96		.96
		> 65		120	86		74	75		1.02		1.18

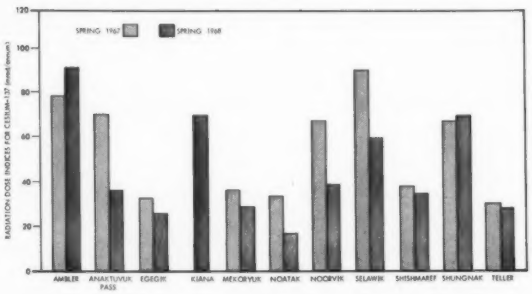

Figure 3. Radiation dose indices for cesium-137, males 45–65 kg

agreement, particularly in the weight range from 50 to 80 kg (figure 1). Thus, the results of Hanson and Palmer (*5–6*) can be directly compared to the studies made by the Bureau of Radiological Health. Cesium-137 burdens were low with a resulting large dispersion of the experimental data in the laboratory calibration.

For each village, a statistical test was performed on the data to determine if there were significant differences between the 1967 and 1968 values. The tests were made only on those individuals in the ten villages who had been counted both years (table 4). The structure of the test was the standard t-test for comparing two means. At the 95-percent confidence level ($\alpha = 0.05$), the populations in four villages (Noatak, Noorvik, Selawik, and Teller) had significant differences between the 1967 and 1968 body burdens. At the 99-percent confidence level, the populations in two villages (Noatak and Noorvik) had significant differences. The authors conclude that the lower levels found in 1968 in Noorvik and Noatak are significant reductions but a statement of a general reduction in all villages and individuals would be unwarranted. It would appear that it is not possible to predict any long-term trend from the present data.

REFERENCES

(*1*) RECHEN, H. J. L., R. L. MIKKELSEN, O. G. BRISCOE and J. F. STEINER, JR. Cesium–137 concentrations in Alaskans during the spring of 1967. Radiol Health Data Rep 9:705–717 (December 1968).

(*2*) PALMER, H. E. Simplified whole body counting. Health Physics 12:95–96 (January 1966).

(*3*) BRUCE, D. W., D. G. REMARK, and W. J. AVERETT. Cesium–137 body burdens of Alaskan men, spring 1965. Public Health Rep 80:949–953 (November 1965).

(*4*) FITZPATRICK, D. E. P., J. L. RUSSELL, O. G. BRISCOE, and C. R. CALVERT. Cesium–137 body burdens in Alaskan men, spring 1966. Radiol Health Data Rep 7:691–696 (December 1966).

(*5*) HANSON, W. C. and H. E. PALMER. Seasonal cycle of ^{137}Cs in some Alaskan natives and animals. Health Physics 11:1401–1406 (December 1965).

(*6*) HANSON, W. C. Cesium–137 in Alaskan lichens, caribou, and Eskimos. Health Physics 13:383–389 (April 1967).

(*7*) FEDERAL FIELD COMMITTEE FOR DEVELOPMENT PLANNING IN ALASKA. Alaska Natives and the Land. (October 1968) pg. 52.

Table 4. Comparison of village populations counted 1967–1968[a]

Village	1967			1968			Differences in means $\bar{x}(1968) - \bar{x}(1967)$	Level of significance $\alpha = .05$	Level of significance $\alpha = .01$
	Number counted (n)	Concentration (nCi/kg)		Number counted (n)	Concentration (nCi/kg)				
		Mean ($\bar{x}$)	Deviation (s)		Mean ($\bar{x}$)	Deviation (s)			
Ambler	53	8.04	3.28	53	7.65	3.83	0.39	No	No
Anaktuvuk	26	6.11	2.78	26	5.58	1.97	.53	No	No
Egegik	55	2.93	2.43	55	2.97	1.46	.04	No	No
Mekoryuk	45	3.11	1.20	45	3.01	1.14	.10	No	No
Noatak	60	4.04	2.16	60	2.48	1.36	1.56	Yes (decrease)	Yes
Noorvik	72	7.58	3.57	72	4.24	2.08	3.34	Yes (decrease)	Yes
Selawik	71	8.63	3.43	71	7.32	2.91	1.31	Yes (decrease)	No
Shishmaref	69	4.06	1.84	69	3.73	1.57	.33	No	No
Shungnak	53	7.40	3.20	53	7.22	3.80	.18	No	No
Teller	32	2.61	1.47	32	3.33	1.70	.72	Yes (increase)	No

[a] Total number individuals counted in both 1967 and 1968 is 536.

Tritium Body Burden of Children, 1967-1968

A. A. Moghissi and *Robert Lieberman*[1]

The tritium concentration in body water of children was determined from samples of urine taken from two children in each of nine Institutional Total Diet Sampling stations. The tritium concentrations in body water of children gradually decreased from about 1.5 nCi/liter to less than 0.2 nCi/liter during the period, January 1967 to December 1968. Several anomalies were noted.

The dose equivalent from tritium for standard man was calculated to be 0.15 mrem for 1967 and 0.13 mrem for 1968. The dose equivalent for children varies according to age and is roughly 0.1 mrem for a 13-year-old child.

After the cessation of atmospheric nuclear testing, tritium concentration in the environment has continuously decreased. Tritium is, however, produced in nuclear reactors and is eventually introduced into the hydrosphere. The Bureau of Radiological Health (BRH) has recognized the importance of this radionuclide and has established a number of networks to evaluate a possible radiation hazard to the public. Analytical results of surface water networks (*1*) are continuously reported. Similarly, rain is continuously monitored for tritium (*2*).

The ultimate purpose of most networks is the evaluation of the radiation dose or, to be more explicit, the dose equivalent (DE) to man. The most suitable medium for the radiobioassay of tritium is body water. It is well known that tritiated water introduced into the body is evenly distributed in the body water within a short period of time. (*3*).

The body burden may thus be expressed as the concentration of tritium in the body water, and urine may be used for radiobioassay and the evaluation of DE. In connection with the Institutional Total Diet Sampling Network Program (ITDSNP) (*4*), urine samples from children in several children's homes were analyzed for a number of radionuclides at the Southeastern Radiological Health Laboratory. During the 1967–1968 period a portion of these samples was radioassayed for tritium.

[1] Dr. Moghissi is with Southwestern Radiological Health Laboratory, Las Vegas, Nev., and Mr. Lieberman is with Southeastern Radiological Health Laboratory, Montgomery, Ala.

Sampling and analysis procedures

Samples were collected from 9 ITDSNP stations distributed throughout the continental United States. The locations of these stations are shown in figure 1. To obtain a reasonable sampling accuracy, samples were collected from two children from each home. Samples were collected in disposable containers and an aqueous (1 ml) solution of merthiolate was used as a preservative. Upon arrival at the laboratory, the samples were logged and stored in a cold room at a temperature of 0–4° C.

Approximately 30 ml of the urine were distilled in all glass equipment using potassium persulfate as an oxidizing agent (*5*). Tritium assay was carried out by liquid scintillation counting, using a dioxane-based scintillation liquid (*5*). Twenty ml of dioxane, containing 7 g of 2,5 diphenyloxazole (PPO) and 1.5 g of p-bis-(methylstyryl)-benzene (bis-MSB) in 1 liter, was mixed with 5 ml of distilled urine and counted in a Beckman liquid scintillation counter. Duplicate samples were prepared and each was counted for 50 minutes twice. A background sample was counted prior to the first sample and a second background sample counted after the second replicates. If any one of the 50-minute sample counts deviated by more than 2 σ from the average, the duplicates were recounted. The minimum limit of detection (MLD) of this system at 2 σ confidence level was 0.2 nCi/liter. Beginning with the July 1968 samples, one of the replicates was counted using a suspension technique (*6*). A p-xylene solution containing 7 g

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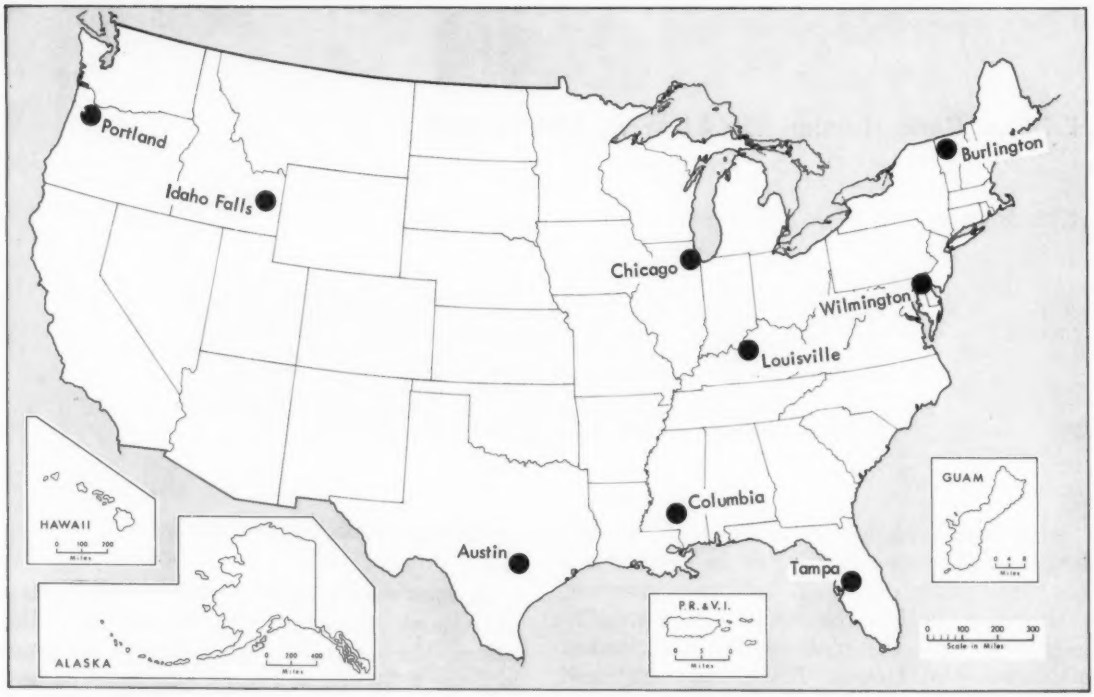

Figure 1. Nine Institutional Total Diet Sampling stations)

PPO and 1.5 g bis-MSB/liter was mixed with a detergent, Triton N101 (a product of Rohm and Haas, Philadelphia, Pa.), in a volume ratio of 2.75:1. Fifteen ml of xylene-detergent mixture and 10 ml of water were thoroughly mixed and counted. The details of this procedure are described by Lieberman and Moghissi (*6*). The minimum limit of detection of this suspension technique was 0.1 nCi/liter.

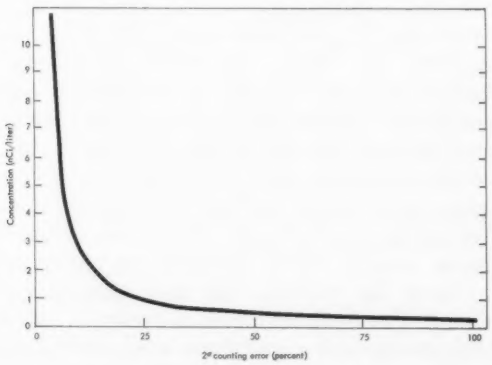

Figure 2. Correlation between the tritium concentration of water and the counting error in percent at 2-sigma confidence level

Although the samples counted during the latter part of 1968 had a lower minimum limit of detection, for the sake of uniformity and because the new procedure was in an experimental state, 0.2 nCi/liter is used as the MLD for the entire period. Figure 2 shows the counting error at 95-percent confidence level for the activity range of this investigation.

Results

From tables 1 and 2, it may be seen that tritium concentrations in the body water of children have gradually decreased in some cases, from approximately 1.5 nCi/liter to less than 0.2 nCi/liter from January 1967 to December 1968.

Certain anomalies are, however, striking. In several cases, the two samples collected from children in the same home show considerable discrepancy. Originally, this was attributed to analytical inaccuracies. In all these cases, however, a rerun of the samples confirmed the original findings.

In search for a reason, a number of possibilities were considered. The water or food intake was the first possibility. It is, however, highly improbable

Table 1. Tritium concentration in urine, 1967

Location	Concentration (nCi/liter)											
	January	February	March	April	May	June	July	August	September	October	November	December
Vt: Burlington	1.8 1.7	1.5 1.4	1.4 1.5	1.5 NS	1.0 .7	0.5 .9	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS
Del: Wilmington	1.2 1.3	.6 1.3	.8 .8	.5 .4	NS .4	.5 .4	0.4 .6	1.3 1.4	0.4 NS	0.3 .3	NS NS	0.3 .2
Ky: Louisville	4.0 1.8	3.0 1.3	3.2 1.1	1.0 1.0	1.8 .5	.8 .4	1.2 .8	2.8 1.8	.9 .8	NS NS	.5 .6	NS NS
Fla: Tampa	1.0 1.0	NS NS	.5 .4	.5 .7	< .2 < .2	.2 < .2	.2 < .2	< .2 .2	.4 3.0	NS NS	NS NS	< .2 < .2
Miss: Columbia	1.6 1.2	.4 .5	.7 .6	.4 < .2	.3 .3	.2 < .2	< .2 < .2	.8 .8	.2 < .2	< .2 < .2	.2 .4	.2 < .2
Ill: Chicago	1.6 1.3	.6 NS	.6 .6	.7 .6	.7 .5	.3 .5	.4 .4	1.2 .8	NS NS	.4 .4	NS NS	.2 < .2
Ore: Portland	.8 NS	1.2 NS	1.2 1.0	.6 .5	.4 .3	.3 .3	NS NS	NS NS	.4 .2	.3 < .2	NS NS	NS NS
Tex: Austin	1.3 1.2	.9 .8	.9 .9	.9 .6	.3 .2	.3 < .2	.4 NS	.8 6.0	.6 4.9	.4 NS	.3 .4	< .2 .3
Idaho: Idaho Falls	1.4 1.3	NS NS	1.3 1.0	1.0 1.0	.4 .8	.5 .7	1.0 .8	12.0 .9	.4 NS	.2 .6	NS NS	.5 3.8

NS, no sample.

Table 2. Tritium concentration in urine, 1968

Location[a]	Concentration (nCi/liter)											
	January	February	March	April	May	June	July	August	September	October	November	December
Del: Wilmington	0.2 < .2	<0.2 < .2	0.5 1.0	0.5 < .2	0.2 .5	1.9 1.2	0.4 < .2	0.9 .8	0.2 .4	<0.2 < .2	0.2 .2	7.2 .4
Ky: Louisville	.6 .4	.5 .9	.2 NS	.5	.4	.8 .4	.5 NS	.5 NS	.5 NS	1.4 NS	.3 NS	.5
Fla: Tampa	4.5 9.6	< .2 < .2	NS NS	< .2 .4	< .2 .2	.2 .2	< .2 < .2	.2 < .2	.4 .8	< .2 < .2	< .2 NS	.4 NS
Miss: Columbia	.5 < .2	.4 2.2	2.0 < .2	.2 < .2	2.4 .4	.4 4.0	< .2 < .2	< .2 .4	1.0 .7	< .2 < .2	< .2 NS	< .2 < .2
Ill: Chicago	.2 5.7	.9 2.0	< .2 4.0	2.0 .9	.4 < .2	NS NS	NS NS	.4 .4	NS NS	NS NS	NS NS	NS NS
Ore: Portland	< .2 < .2	NS NS	.6 < .2	6.0 < .2	.2 .2	.6 .4	< .2 < .2	< .2 < .2	1.0 .8	< .2 .6	< .2 < .2	6.0 < .2
Tex: Austin	NS NS	< .2 < .2	< .2 < .2	< .2 < .2	< .2 < .2	.2 .4	.4 .4	< .2 < .2	< .2 < .2	1.0 < .2	< .2 < .2	.2 .8
Idaho: Idaho Falls	5.0 4.7	.9 2.0	1.4 .9	.8 .6	.5 .7	.5 .5	1.0 .8	NS NS	1.0 1.0	.5 < .2	.6 .8	1.0 1.0

[a] No samples were received from Burlington, Vt., during 1968
NS, no sample received.

that a person living in Tampa, Fla., would have a tritium body burden of 9.6 or 4.5 nCi/liter (January 1968) as water collected in that area had a tritium concentration of less than 0.2 nCi/liter. Tritium concentration in food collected during the same month was less than 0.2 nCi/liter (7) of water of combustion.

It is also unusual that two children from Wilmington, Del., having essentially the same tritium intake, show differences of almost 7 nCi/liter (December 1968).

A second possibility is the contamination of the sample during the sample collection and analysis. This possibility was systematically investigated. Forty-five disposable containers randomly selected from a variety of shipments were filled with 1 liter of water and left in the cold room for 14 days. These water samples were subse-

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quently processed in the same manner as the urine samples and counted. No case of increased activity could be observed.

The only other possibility was the contamination of the samples during the shipment. One characteristic of the samples showing anomalies was their condition on arrival. They were generally spoiled, presumably due either to improper preservation or because the container was washed prior to sample collection, thus removing the preservative.

It is known that the specific activity of hydrogen (*8*) and methane (*9*) in the atmosphere is several orders of magnitude higher than that of atmospheric moisture. If during the biochemical reactions that occur during spoiling of urine samples, methane becomes incorporated into the aqueous portion of the urine, then an increased specific activity may result. The true reason for the relatively high specific activities found remains unknown for the time being. Further investigations are necessary to clarify this phenomenon.

Dose calculations

Moghissi and Porter (*1*) proposed the following equation for the calculation of tritium dose under equilibrium conditions:

$$DE = 10^{-1}C(QF)$$

where,

DE = dose equivalent in mrem/a;
C = concentration of tritium in the body in nCi/liter; and,
QF = quality factor for tritium.

This equation assumes a body weight of 70 kg of which 10 percent is hydrogen. To facilitate the dose calculation, it is assumed that the hydrogen concentration of the body is essentailly independent of age. This assumption is substantiated by the findings of Forbes (*10*) who has shown that the body water to body weight ratio changes only slightly with age. He also determined the body weight of children as shown in table 3. As the sex of the children was not recorded, the average weights were used in the calculations.

Since the publication of the above equation, Evans (*11*) has found that under continuous exposure, the specific activity of organically-bound and aqueous hydrogen is essentially the same. This finding confirms the underlying idea leading to that equation and is in conflict with the recommendations of ICRP (*12*).

Table 3. Body weight of children

Age (years)	Weight (kg)		
	Male	Female	Average
9	30.5	32	31.25
10	32	35	33.5
11	37	38	37.5
12	43.5	41	42.25
13	45	48	46.5
14	51	56	53.5

Numerous investigations have been published recently dealing with the quality factor (QF) of tritium. Feinendegen (*13*) has reviewed the literature extensively. Vennart (*14*) in a recent review has proposed a QF of 1. It is unfortunate that none of these papers reviews Shtukkenberg's (*15*) paper where a QF of 3 was proposed. Although Lambert (*16*) found recently that a QF of 1.3–2.4 was more appropriate, the International Commission on Radiological Protection decided to follow Vennart's recommendation (*17*) and has proposed a QF of 1 for tritium. Since no definite decision has been made by the National Commission on Radiation Protection and Measurements, a QF of 1.7 was found to be appropriate and is used in the calculations.

To evaluate the dose, all values of less than 0.2 nCi/liter are assumed to be 0.1 nCi/liter. This

Table 4. Average tritium concentrations in urine of children, total body burden, and dose equivalents for the standard man

Location	1967			1968		
	Concentration in urine (nCi/liter)	Total body burden (nCi)	Dose equivalent (mrem)	Concentration in urine (nCi/liter)	Total body burden (nCi)	Dose equivalent (mrem)
Vt: Burlington	1.26	79.4	0.21			
Del: Wilmington	.67	42.2	.11	0.72	45.4	0.12
Ky: Louisville	1.46	92.0	.25	.56	35.3	.10
Fla: Tampa	.48	30.2	.08	.89	56.1	.15
Miss: Columbia	.40	25.2	.07	.68	42.8	.12
Ill: Chicago	.62	39.1	.11	1.42	89.5	.24
Ore: Portland	.54	34.0	.09	.79	49.8	.13
Tex: Austin	1.02	64.3	.17	.22	13.9	.04
Idaho: Idaho Falls	1.50	94.5	.26	1.20	75.6	.20
Average	0.88	55.6	0.15	0.81	51.0	0.13

value is estimated to be the current tritium level in surface waters of low specific tritium activity. Also high values are used in the averaging process although there is a probability that the calculated dose would be somewhat too high.

Table 4 shows the average tritium concentrations in the body water of children at the various sampling stations. The total body burdens are calculated for standard man, assuming that the tritium concentration in the body of standard man would be essentially the same as that in the bodies of children. The DE is calculated also for standard man and is included in the tables. The DE for standard man during 1967 was 0.15 mrem and during 1968, 0.13 mrem.

Table 5 shows the average total body burden and the DE for various ages calculated for the average tritium concentration.

Table 5. Tritium total body burden (TBB) and the dose equivalents (DE) of children during 1967 and 1968

Age (years)	Total body burden (nCi)		Dose equivalents (mrem)	
	1967	1968	1967	1968
9	24.8	22.8	0.067	0.061
10	26.6	24.4	.071	.066
11	29.8	27.3	.080	.074
12	33.5	30.8	.090	.083
13	36.9	33.8	.099	.091
14	42.5	38.9	.114	.105

The DE for children varies according to age and is roughly 0.1 mrem for a 13-year-old child.

REFERENCES

(1) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters of the United States 1966. Radiol Health Data Rep 9:337 (1968); 1967, 9:564 (1968); January–June 1968, 9:665 (1968); July–December 1968, 10:263 (1969).

(2) MOGHISSI, A. A. and C. R. PORTER. Tritium concentration in precipitation Radiol Health Data Rep 11:137–140 (March 1970).

(3) PINSON, E. A., and W. H. LANGHAM. Physiology and toxicology of tritium in man. J Appl Physiol 10:108 (1957).

(4) ANDERSON, F. C. and D. M. NELSON, JR. Surveillance for radiological contamination in food. Amer J Public Health 52:139 (1962). (See also Radiol Health Data Rep for continuous updating of the ITDSNP).

(5) MOGHISSI, A. A., H. L. KELLY, J. E. REGNIER, and M. W. CARTER. Low-level counting by liquid scintillation; I. Tritium measurement in homogeneous system. Inter J Appl Rad Isotopes 20:141 (1969).

(6) LIEBERMAN, R., and A. A. MOGHISSI. Low-level counting by liquid scintillation; II. Application of emulsions to tritium counting. Inter J Appl Rad Isotopes (in press).

(7) MOGHISSI, A. A. and R. J. LYON. Tritium concentration in food, 1967–1968. Radiol Health Data Rep 11:233–236 (May 1970).

(8) BEGEMANN, F. Isotopic composition of atmospheric hydrogen. J Geophys Res 73:1139 (1968).

(9) HAINES, A. and B. C. MUSGRAVE. Tritium content of atmospheric methane and ethane. J Geophys Res 73:1167 (1968).

(10) FORBES, G. B. Changes in Body Water and Electrolyte During Growth and Development in Body Composition in Animals and Man. National Academy of Science, Washington, D.C. (1958) pp. 80–86.

(11) EVANS, A. G. New dose estimates from chronic tritium exposure. Health Phys 16:57 (1969).

(12) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection, report of Committee II on permissible dose for radiation (1959).

(13) FEINENDEGEN, L. E. Tritium Labelled Molecules in Biology and Medicine. Academic Press, New York, N.Y. (1967).

(14) VENNART, J. Radiotoxicology of tritium and ^{14}C compounds. Health Phys 16:429 (1969).

(15) SHTUKKENBERG, Yu M. Application of Tritium in Biological Research, United Nations Scientific Committee on the Effects of Atomic Radiation, A/AC, 82/G/L. 552 (1960) and Nucl Sci Abstr 15:15342 (1961).

(16) LAMBERT, B. E. Cytological damage produced in the mouse testes by tritiated thymicine, tritiated water and γ-rays. Health Phys 17:547 (1969).

(17) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Progress report for ICRP. Health Phys 17:389 (1969).

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Tritium Concentrations in Food, 1967-1968

A. A. Moghissi and R. J. Lyon[1]

Tritium concentrations were determined in food samples obtained from several children's homes in the United States. The average concentrations of tritium in food indicate a decreasing trend from 1967 to 1968. The average dose equivalent from tritium in food was calculated to be 0.08 mrem for 1967 and 0.03 mrem for 1968.

Due to the biological significance of tritium, the Bureau of Radiological Health has for several years evaluated the radiological health aspects of this radionuclide. The results of studies dealing with surface waters, (*1*), rain (*2*), and urine (*3*) have been reported.

According to the recommendations of the International Commission on Radiological Protection (ICRP) (*4*) more than half of the tritium intake is through food. Uncertainties regarding the biological half life of tritium incorporated in the organic molecules of food justified an evaluation of the tritium present in food.

Sampling and analysis procedures

Food samples collected from several children's homes distributed throughout the continental United States were shipped to the Southeastern Radiological Health Laboratory. These homes were instructed to collect the total food intake of the children, including soft drinks, during a period of 24 hours. The only medium not included was tap water.

In the laboratory, the sample was homogenized and approximately 100–150 grams were combusted. The collected water was distilled and counted for tritium.

Combustion procedure

The details of the combustion technique are shown in figure 1. Air is passed through a column (D_1) containing a desiccant and molecular sieve (Linde 13 A) to remove water and organic compounds originating from air compressors. The purified air was passed through a copper oxide catalyst which was kept at 500 to 600° C. in a furnace (F_1). This step was necessary to oxidize hydrogen and methane in the air which are known to contain tritium (*5*, *6*) at levels several orders of magnitude higher than atmospheric moisture. The resulting water was collected in the drying column (D_2). The sample (S) which was placed in the furnace (F_2) was partially combusted as the air passed by. The completion of combustion occurred in the furnace (F_3) in the presence of a copper oxide catalyst at 500–600° C. At the beginning of the process F_2 was gradually heated from room temperature to 600° C. within 2 hours. An additional 2 hours were necessary to remove the possible residues of the sample, making it possible to run two samples in a working day.

Subsequent to the completion of this work, the catalyst was replaced by a platinum-aluminum oxide catalyst[2]. This catalyst could be used at a lower temperature of 150–200° C. and thus was considerably more effective.

Accuracy of the combustion

Significant errors may be introduced in the results of chemical reactions dealing with tritium if the reaction is incomplete. This phenomenon is caused by isotope effect and is the basis for enrichment of deuterium and tritium.

To evaluate the reproducibility of this combustion system, approximately 5 g of a rat tissue from a tritium experiment was mixed with the food and combusted. The entire procedure was

[1] A. A. Moghissi is with Southwestern Radiological Health Laboratory, Las Vegas, Nev., and R. J. Lyon is with Southeastern Radiological Health Laboratory, Montgomery, Ala.

[2] The catalyst was obtained from the Englehard Industries, Newark, N.J.

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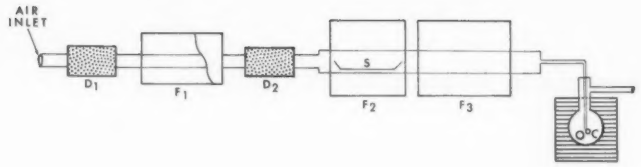

Figure 1. Schematic diagram of the combustion system

then repeated several times. The resulting water samples were distilled and counted as described below. Results of the replicates are shown in table 1. It can be seen that the standard deviation of the mean compares favorably with the counting error of the individual samples at the 2 σ confidence level.

Table 1. Accuracy of the food tritium analysis

Run number	Concentration in water of combustion (nCi/liter)
1	6.1 ± 0.3
2	5.9 ± .3
3	6.3 ± .3
4	6.0 ± .3
5	5.7 ± .3
Average	6.0 ± 0.2

Liquid scintillation counting

All samples were counted in a Beckman liquid scintillation counter. The details of the sample preparation are described by Moghissi et al (*7*). In short, 1 liter of scintillation liquid was prepared by dissolving 7 g of 2, 5-diphenyloxazole (PPO), 1.5 g of p-bis-(methystyryl)-benzene (bis-MSB) and 120 g of naphthalene in dioxane. Duplicate samples were prepared using 20 ml of this scintillation liquid and 5 ml of water. The total counting time for the duplicate was 200 minutes divided into four 50-minute counts. If any of the 50-minute counts deviated by more than 2 σ from the average, the duplicates were recounted. This occurred with a frequency comparable to the statistical expectancy. A background sample was counted prior to the first sample and a second background subsequent to its duplicate. The minimum limit of detection (MLD) of the counting was 0.2 nCi/liter at the 2 σ confidence level. Starting July 1968, one of the replicates was prepared using an emulsion mixture (*8*). A p-xylene solution containing 7 g PPO and 1.5 g bis-MSB per liter was mixed with Triton N 101 in a volume ratio of 2.75:1. Fifteen ml of this mixture were mixed with 10 ml of water resulting in a MLD of 0.1 nCi/liter. As this mixture was used in an experimental stage and for the sake of uniformity, all results are reported with an MLD of 0.2 nCi/liter and the counting error of the dioxane-based solution shown in figure 2.

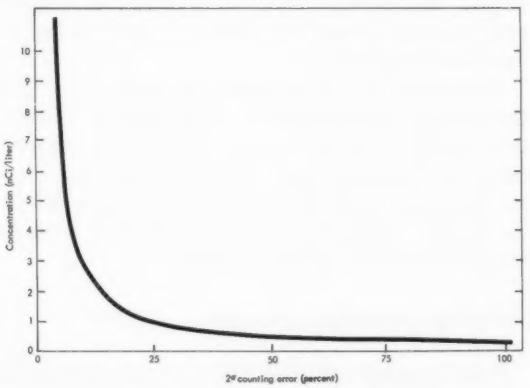

Figure 2. Correlation between the tritium concentration of water and the counting error in percent at 2-sigma confidence level

Results

The location of the stations and the analytical results are shown in tables 2 and 3. The decreasing trend as observed in surface water (*1*), rain (*2*) and urine (*3*) is evident in average values of 1968 as compared to 1967. A clear trend in individual samples is, however, not evident. The October 1968 value from Tampa, Fla., is considerably higher than other values during the entire period of 1967–1968. Similar values may be observed for other sample collection sites (Albuquerque, N. Mex., June 1967; Charleston, S.C., December 1967; etc.). This apparent lack of systematic decrease may be explained by the complexity of the food. Individual components of the samples could have originated from geographical areas

Table 2. Tritium concentration in food, 1967

Location		Concentration (nCi/liter of water of combustion)											
		January	February	March	April	May	June	July	August	September	October	November	December
Fla:	Tampa	0.5	0.5	0.9	0.4	NS	NS	0.5	<0.2	<0.2	0.6	<0.2	<0.2
La:	New Orleans	NS	.4	.5	.3	0.2	1.0	.6	1.0	<0.2	.9	NS	1.0
Ark:	Little Rock	< .2	.5	.4	.5	.2	.4	.3	< .2	NS	.3	.2	.4
Ky:	Louisville	NS	NS	1.0	1.1	> .2	.8	.6	.8	NS	.6	.4	1.0
N. Mex:	Albuquerque	.4	.6	.5	> .2	> .2	1.2	.5	NS	.3	NS	.6	NS
S.C:	Charleston	NS	.6	.6	.3	1.5	> .2	> .2	1.1	.2	.4	NS	2.0
Miss:	Columbia	.3	.3	.8	.4	.4	> .2	1.0	.2	NS	.4	NS	< .2
Tex:	Austin	.3	.6	1.0	> .2	> .2	1.0	NS	< .2	.5	< .2	< .2	< .2

NS, no sample received.

Table 3. Tritium concentration in food, 1968

Location		Concentration (nCi/liter of water of combustion)											
		January	February	March	April	May	June	July	August	September	October	November	December
Fla:	Tampa	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1.3	<0.2	<0.4
La:	New Orleans	< .2	< .2	< .2	< .2	< .2	< .2	NS	< .2	< .2	< .2	.5	< .2
Ark:	Little Rock	< .2	.3	< .2	.2	< .2	< .2	< .2	< .2	< .2	< .2	< .2	< .2
Ky:	Louisville	.4	.3	.3	.3	.2	.2	< .2	.3	.3	.3	NS	.2
N. Mex:	Albuquerque	.4	.3	.4	.2	< .2	< .2	NS	.3	< .2	< .2	NS	.4
S.C:	Charleston	.3	.3	.3	.3	.3	< .2	< .2	NS	.3	.3	.3	.5
Miss:	Columbia	< .2	< .2	< .2	< .2	< .2	< .2	NS	< .2	< .2	.5	NS	.5
Tex:	Austin	< .2	< .2	< .2	.2	< .2	< .2	NS	.2	.3	.5	NS	.6

NS, no sample received.

with different tritium concentrations than the collection site. Similarly, the preservation of food makes it possible that part of the food could have originated at a time when the tritium concentration was higher than that at the collection time. In the averaging process these effects are minimized so that a decrease is evident.

Dose calculation

In order that the dose equivalent to the population could be calculated, the average annual tritium concentration was used. For the purpose of averaging 0.1 nCi/liter was assumed to be the tritium concentration of values below the MLD. The following equation (*1*) was used for dose calculation:

$$DE = 10^{-1}(QF)C \qquad \ldots(1)$$

where

DE = dose equivalent in mrem/a;
QF = quality factor for tritium; and,
C = concentration of tritium in the body in nCi/liter.

Although ICRP has recommended a reduction of QF for tritium from 1.7 to 1, for the sake of uniformity with the dose calculations made for the same period using other media and for reasons described elsewhere (*3*), a QF of 1.7 is used in the dose estimations.

For the purpose of calculation it is assumed that the tritium concentration of the body is in equilibrium with that in food. It can be seen in table 4 that the average DE as calculated for food is somewhat lower than the averages calculated from body burden measurements for standard man of 0.15 mrem for 1967 and 0.13 mrem for 1968. This may be explained by the uncertainties

Table 4. Average tritium concentrations in food and the dose equivalents

Location	1967		1968	
	Concentration (nCi/liter)	Dose equivalent (mrem)	Concentration (nCi/liter)	Dose equivalent (mrem)
Fla: Tampa	0.38	0.06	0.14	0.02
La: New Orleans	.60	.10	.14	.02
Ark: Little Rock	.34	.06	.13	.02
Ky: Louisville	.71	.12	.26	.04
N. Mex: Albuquerque	.48	.08	.24	.04
S. C: Charleston	.69	.12	.26	.04
Miss: Columbia	.40	.07	.18	.03
Tex: Austin	.36	.06	.23	.04
Annual average	0.49	0.08	0.20	0.03

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associated with the urine values (*3*) and the fact that an additional source of tritium intake, i.e., drinking water, is not considered if the DE calculation is based on food intake.

The above calculations are valid for standard man with a body weight of 70 kg and a hydrogen body content of 7,000 grams. The DE to children who actually consumed this food depends upon the body weight and the hydrogen content of the body. An estimate of DE of children may be carried out by the method described elsewhere (*3*).

REFERENCES

(*1*) MOGHISSI, A. A. and C. R. PORTER. Tritium in surface waters of the United States, 1966. Radiol Health Data Rep 9:337, (1968); 1967, 9:564 (1968); January–June 1968, 9:665 (1968); July–December 1968, 10:263 (1969).

(*2*) MOGHISSI, A. A. and C. R. PORTER. Tritium concentration in precipitation. Radiol Health Data Rep 11:137–140 (March 1970).

(*3*) MOGHISSI, A. A. and R. LIEBERMAN. Tritium body burdens of children 1967–1968. Radiol Health Data Rep 11:227–231 (May 1970).

(*4*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection, Report of Committee II on permissible dose for internal radiation (1959) p. 152.

(*5*) BEGEMANN, F. Isotopic composition of atmospheric hydrogen. J Geophys Res 73:1139 (1968).

(*6*) HAINES, A. and B. C. MUSGRAVE. Tritium content of atmospheric methane and ethane. J Geophy Res 73:1167 (1968).

(*7*) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low-level counting by liquid scintillation I. Tritium measurement in homogeneous systems. Inter J Appl Rad Isotopes 20:141 (1969).

(*8*) LIEBERMAN, R. and A. A. MOGHISSI. Low-level counting by liquid scintillation II. Applications of emulsions in tritium counting. Inter J Appl Rad Isotopes (in press).

(*9*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Progress report from ICRP. Health Phys 17:389 (1969).

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SECTION I. MILK AND FOOD

Milk Surveillance, January 1970

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network, (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Foods, Pesticides, and Product Safety, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in or are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both

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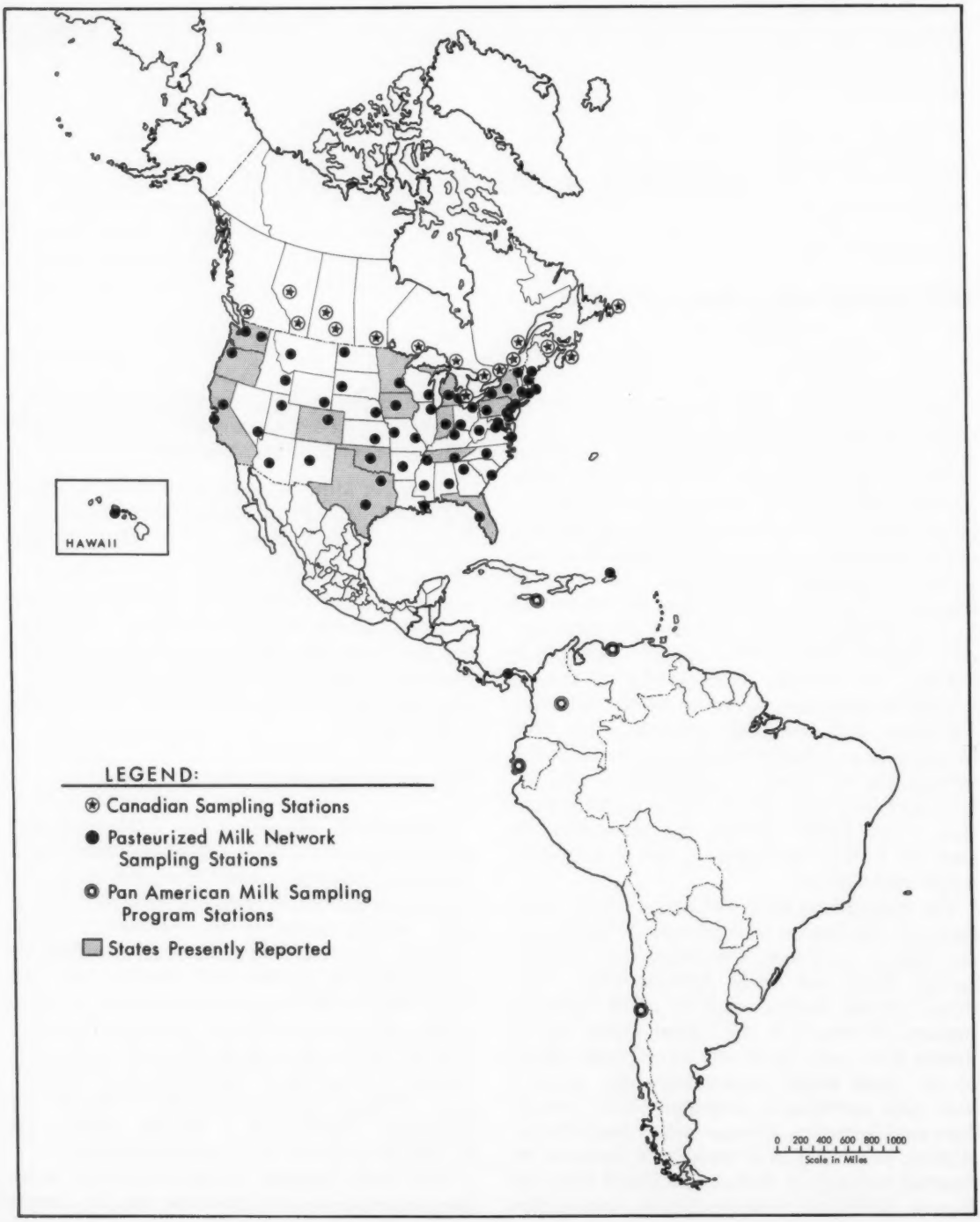

Figure 1. Milk sampling networks in the Western Hemisphere

calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the period, July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 15 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good, which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short-time periods and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention

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was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium–90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result due to exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Radionuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c]1.5	0.5	[d]2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c]1.5	.5	[d]200	0–20	20–200	200–2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0–10	10–100	100–1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c]1,110,000
Strontium-90	Bone marrow			[c]51,000
Cesium-137	Whole body			[c]720,000
Iodine-131	Thyroid	30	10	[d]70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

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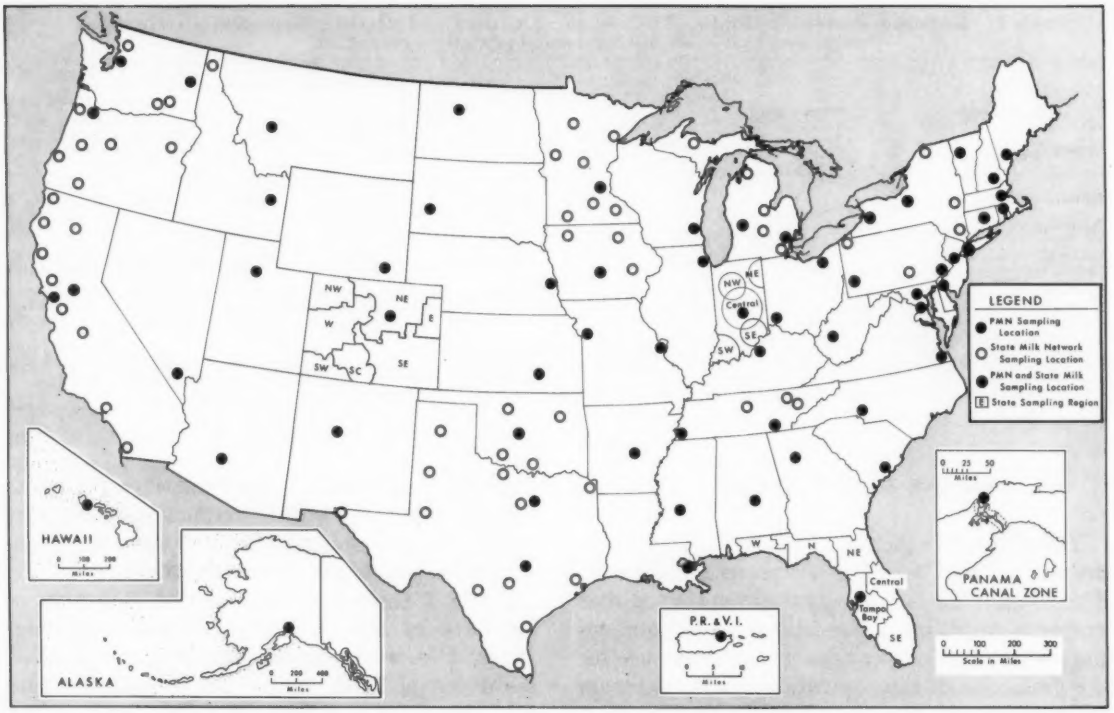

Figure 2. State and PMN milk sampling locations in the United States

an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in a retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. The relationship between the PMN stations and State stations is shown in figure 2. The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-month averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137 for January 1970 and the 12-month period, February 1969 to January 1970. Except where noted, the

Table 3. Concentration of radionuclides in milk for January 1970 and 12-month period, February 1969 through January 1970

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	3	7	0(4)	0	10(4)	10
Alaska:	Palmer[c]	P	4	6	0(4)	0	7(4)	6
Ariz:	Phoenix[c]	P	2	1	0(5)	0	0(5)	0
Ark:	Little Rock[c]	P	14	16	0(4)	0	18(4)	18
Calif:	Sacramento[c]	P	0	1	0(5)	0	0(5)	0
	San Francisco[c]	P	0	2	0(4)	0	0(4)	0
	Del Norte	P	12	19	0	0	20	21
	Fresno	P	2	2	0	0	2	5
	Humboldt	P	4	5	0	0	6	8
	Los Angeles	P	2	2	0	0	3	3
	Mendocino	P	3	4	0	0	6	5
	Sacramento	P	2	3	0	0	8	5
	San Diego	P	2	2	0	0	1	3
	Santa Clara	P	2	2	0	0	7	5
	Shasta	P	2	3	0	0	4	6
	Sonoma	P	2	3	0	0	13	6
Colo:	Denver[c]	P	7	5	0(4)	0	0(4)	1
	West	R	[d]		NS	[e]	NS	[e]
	Northeast	R	[d]		[e]	[e]	[e]	[e]
	East	R	[d]		[e] (2)	[e]	[e]	[e]
	Southeast	R	[d]		NS	[e]	NS	[e]
	South Central	R	[d]		NS	[e]	NS	[e]
	Southwest	R	[d]		[e]	[e]	[e]	[e]
	Northwest	R	[d]		NS	[e]	NS	[e]
Conn:	Hartford[c]	P	10	8	0(5)	0	7(5)	11
	Central	P	7	7	0(5)	0	7(5)	11
Del:	Wilmington[c]	P	7	8	0(4)	0	0(4)	6
D.C.:	Washington[c]	P	5	7	0(5)	0	0(5)	4
Fla:	Tampa[c]	P	6	6	0(4)	0	45(4)	54
	West	R	9	13	0	0	14	25
	North	R	7	13	0	0	17	26
	Northeast	R	6	8	0	0	30	54
	Central	R	7	8	0	0	30	56
	Tampa Bay area	R	8	8	0	0	40	56
	Southeast	R	7	8	0	0	59	86
Ga:	Atlanta[c]	P	10	10	0(4)	0	18(4)	19
Hawaii:	Honolulu[c]	P	3	3	0(4)	0	0(4)	0
Idaho:	Idaho Falls[c]	P	6	5	0(4)	0	1(4)	4
Ill:	Chicago[c]	P	7	7	0(4)	0	5(4)	8
Ind:	Indianapolis[c]	P	7	8	0(4)	0	4(4)	5
	Northeast	P	6	10	15	1	15	10
	Southeast	P	9	8	0	0	10	11
	Central	P	6	8	0	0	10	10
	Southwest	P	8	9	0	0	25	13
	Northwest	P	8	10	0	0	15	17
Iowa:	Des Moines[c]	P	7	6	0(4)	0	0(4)	2
	Iowa City	P	NS		NS		NS	
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	9	7	0(4)	0	0(4)	1
Ky:	Louisville[c]	P	6	8	0(4)	0	5(4)	4
La:	New Orleans[c]	P	NS	16	NS	0	NS	18
Maine:	Portland[c]	P	9	11	0(4)	0	20(4)	23
Md:	Baltimore[c]	P	9	8	0(4)	0	1(4)	6
Mass:	Boston[c]	P	5	11	0(4)	0	18(4)	22
Mich:	Detroit[c]	P	10	8	0(4)	0	6(4)	9
	Grand Rapids[c]	P	11	10	0(4)	0	7(4)	13
	Bay City	P	10	9	[e] (2)	[e]	13(2)	8
	Charlevoix	P	13	10	[e] (4)	[e]	14(4)	18
	Detroit	P	9	6	[e] (4)	[e]	6(4)	6
	Grand Rapids	P	8	8	[e] (4)	[e]	11(4)	13
	Lansing	P	8	7	[e] (3)	[e]	16(2)	13
	Marquette	P	13	11	[e] (2)	[e]	19(2)	26
	Monroe	P	8	5	[e] (2)	[e]	0(2)	2
	South Haven	P	NS	7	NS	[e]	NS	10
Minn:	Minneapolis[c]	P	9	10	0(4)	0	0(4)	8
	Bemidji	P	16	17	0	0	24	24
	Mankato	P	3	9	0	0	11	0
	Rochester	P	6	8	0	0	11	0
	Duluth	P	18	19	0	0	23	23
	Worthington	P	4	7	0	0	0	0
	Minneapolis	P	10	12	0	0	22	0
	Fergus Falls	P	5	9	0	0	14	0
	Little Falls	P	6	9	0	0	0	0
Miss:	Jackson[c]	P	16	12	0(5)	0	8(5)	13
Mo:	Kansas City[c]	P	6	7	0(4)	0	0(4)	1
	St. Louis[c]	P	7	8	0(5)	0	0(5)	2
Mont:	Helena[c]	P	6	5	0(4)	0	7(4)	5
Nebr:	Omaha[c]	P	5	6	0(5)	0	0(5)	1
Nev:	Las Vegas[c]	P	3	1	0(4)	0	0(4)	0

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for January 1970 and 12-month period, February 1969 through January 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
N.H.:	Manchester[c]	P	9	8	0(4)	0	17(4)	19
N.J.:	Trenton[c]	P	8	9	0(4)	0	4(4)	7
N. Mex:	Albuquerque[c]	P	2	2	0(4)	0	0(4)	0
N.Y.:	Buffalo[c]	P	7	7	0(3)	0	5(3)	9
	New York City[c]	P	5	10	0(4)	0	8(4)	12
	Syracuse[c]	P	7	7	0(4)	0	14(4)	10
	Albany	P	NS	5	NS	0	NS	(e)
	Buffalo	P	NA	0	0	0	(e)	(e)
	Massena	P	5	8	0(3)	0	(e) (3)	(e)
	Newburg	P	8	8	0	0	(e)	(e)
	New York City	P	7	8	0(6)	0	(e) (6)	(e)
	Syracuse	P	3	4	0(1)	0	(e)	(e)
N.C.:	Charlotte[c]	P	12	12	0(4)	0	11(4)	13
N. Dak:	Minot[c]	P	8	10	0(4)	0	14(4)	13
Ohio:	Cincinnati[c]	P	8	8	0(4)	0	0(4)	3
	Cleveland[c]	P	10	9	0(5)	0	3(5)	6
Okla:	Oklahoma City[c]	P	7	7	0(4)	0	7(4)	9
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Ore:	Portland[c]	P	5	6	0(5)	0	0(5)	6
	Baker	P	NA	2	(e)	(e)	(e)	5
	Coos Bay	P	6	6	(e)	(e)	17	12
	Eugene	P	5	4	(e)	(e)	(e)	8
	Medford	P	2	2	(e)	(e)	(e)	13
	Portland composite	P	NA	4	(e)	(e)	7(5)	6
	Portland local	P	4	5	(e)	(e)	12(4)	9
	Redmond	P	NA	2	(e)	(e)	21	3
	Tillamook	P	4	6	(e)	(e)	15	14
Pa:	Philadelphia[c]	P	9	9	0(4)	0	4(4)	4
	Pittsburgh[c]	P	5	11	0(4)	0	6(4)	8
	Dauphin	P	8	7	11	1	26	14
	Erie	P	7	10	15	6	25	22
	Philadelphia	P	8	7	0	5	0	8
	Pittsburgh	P	10	10	0	2	17	18
R.I.:	Providence[c]	P	9	9	0(4)	0	15(4)	16
S.C.:	Charleston[c]	P	7	10	0(4)	0	20(4)	23
S. Dak:	Rapid City[c]	P	9	8	0(5)	0	2(5)	5
Tenn:	Chattanooga[c]	P	10	10	0(4)	0	14(4)	13
	Memphis[c]	P	10	8	0(4)	0	5(4)	5
	Chattanooga	P	9	13	0(3)	0	11(3)	15
	Clinton	P	10	15	0	1	15	14
	Knoxville	P	6	10	0(2)	0	7(2)	5
	Nashville	P	7	8	0	0	0	4
Tex:	Austin[c]	P	3	2	0(3)	0	4(3)	4
	Dallas[c]	P	2	6	0(4)	0	3(4)	6
	Amarillo	R	NS	4	NS	0	NS	0
	Corpus Christi	R	NS	4	NS	0	NS	0
	El Paso	R	NS	2	NS	0	NS	0
	Fort Worth	R	5	6	0	0	10	5
	Harlingen	R	NS	3	NS	0	NS	0
	Houston	R	10	8	0	0	15	15
	Lubbock	R	NS	4	NS	0	NS	0
	Midland	R	2	2	0	0	0	0
	San Antonio	R	NS	4	NS	0	NS	0
	Texarkana	R	NS	10	NS	0	NS	13
	Uvalde	R	NS	2	NS	0	NS	0
	Wichita Falls	R	NS	6	NS	0	NS	8
Utah:	Salt Lake City[c]	P	3	4	0(4)	0	5(4)	4
Vt:	Burlington[c]	P	9	8	0(4)	0	6(4)	13
Va:	Norfolk[c]	P	9	10	0(5)	0	10(5)	8
Wash:	Seattle[c]	P	3	7	0(4)	0	1(4)	11
	Spokane[c]	P	5	6	0(4)	0	0(4)	4
	Benton County	R	0	1	0	0	14	7
	Franklin County	R	NS	0	NS	0	NS	0
	Sandpoint, Idaho	R	12	11	0	0	17	27
	Skagit County	R	6	7	0	0	0	13
W. Va:	Charleston[c]	P	9	9	0(4)	0	7(4)	7
Wisc:	Milwaukee[c]	P	6	7	0(5)	0	10(5)	11
Wyo:	Laramie[c]	P	7	6	0(4)	0	0(4)	4
CANADA:								
Alberta:	Calgary	P	8	8	(d)		21	16
	Edmonton	P	6	7	(d)		21	14
British Columbia:	Vancouver	P	8	11	(d)		30	31
Manitoba:	Winnipeg	P	8	8	(d)		22	25
New Brunswick:	Fredericton	P	10	13	(d)		21	17
Newfoundland:	St. Johns	P	16	17	(d)		27	33

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for January 1970 and 12-month period, February 1969 through January 1970—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
Nova Scotia:	Halifax	P	10	10	[d]		16	19
Ontario:	Ft. William	P	12	15	[d]		30	30
	Ottawa	P	6	8	[d]		9	13
	Sault Ste. Marie	P	11	15	[d]		19	29
	Toronto	P	6	5	[d]		10	10
	Windsor	P	7	6	[d]		15	11
Quebec:	Montreal	P	8	8	[d]		19	18
	Quebec	P	11	11	[d]		23	25
Saskatchewan:	Regina	P	5	7	[d]		12	12
	Saskatoon	P	7	8	[d]		6	12
CENTRAL AND SOUTH AMERICA:								
Columbia:	Bogota	P	2	2	0	0	10	3
Chile:	Santiago	P	0	0	0	0	0	2
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Kingston	P	4	4	0	0	45	85
Venezuela:	Caracas	P	2	2	0	0	0	0
Canal Zone:	Cristobal[c]	P	0	0	0(4)	0	9(4)	9
Puerto Rico:	San Juan[c]	P	3	3	0(4)	0	8(4)	7
PMN network average[f]			7	7	0	0	6	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote [c].

NA, no analysis.
NS, no sample collected.

monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for January 1970 were below the respective practical reporting levels. Averages for those stations at which strontium-89 was detected were Del Norte, Calif., 8 pCi/liter; Minot, N. Dak., 9 pCi/liter; and Dallas, Tex., 6 pCi/liter.

Iodine-131 results are included in the table even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 18 pCi/liter in the United States for the month of January 1970, and the highest 12-month average was 19 pCi/liter (Del Norte, Calif., and Duluth, Minn.), representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 59 pCi/liter in the United States for the month of January 1970, and the highest 12-month average was 86 pCi/liter (Southeast Florida) representing 2.4 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level except Dauphin, Pa., 11 pCi/liter and Erie, Pa., 15 pCi/liter.

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California State Department of Health

Radiological Health Section
Division of Air, Occupational, and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium–90, iodine–131, and other radionuclides in milk, May 1957 through April 1958. Amer J Public Health 49:225 (February 1959).

(2) Chart of the Nuclides, Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).

(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(4) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(5) KNOWLES, F. Interlaboratory study of iodine–131, cesium–137, barium–140, strontium–89, and strontium–90 measurements in milk, July–December 1969. Technical experiment 69–MKAQ–2, Analytical Quality Control Service, Bureau of Radiological Health (October 1969).

(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).

(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(8) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(9) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(10) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(11) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(12) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The Cause of Relatively High Cesium–137 Concentrations in Tampa, Florida, Milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y., (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Issue
Connecticut Diet Study	July–December 1968, and January–June 1969	February 1970
Radionuclides in Institutional Diet Samples, *PHS*	April–June 1969	January 1970
Strontium–90 in Tri-City Diets, *HASL*	August–December 1968	December 1969

1. Estimated daily intake of radionuclides in California diets, October–December 1968 and January–March 1969

Bureau of Radiological Health
California State Department of Public Health

The Bureau of Radiological Health, California State Department of Public Health, has made estimates of radionuclide levels in the diets of Californians since January 1964 (*1*).

It is recognized that a "standard" or "typical" diet does not exist because of variations in individual tastes, therefore an effort was made to select a diet which was reasonably representative of the food consumed in a given area. This objective was met by utilizing the "house" diet of a hospital in each of the 20 geographic areas of interest (figure 1).

Hospitals were chosen as the source of diet samples under the hypothesis that their diets are as "reasonably representative" as any other. General hospitals exist in each of the 20 selected geographic areas and operate with trained dietitians. There is good reason to believe that hospitals utilize foods which are marketed in their respective communities. Also, working relations for entry into hospitals existed through the State Bureau of Nutrition and Hospitals.

Sampling procedure

In general, the sampling procedure is the same at each hospital. Samples are collected every 3 months at each facility. Each sample represents the edible portion of a regular meal (the standard diet) for a full 7-day week (21 consecutive meals).

After each sample is collected, it is suitably preserved and shipped to the Sanitation and

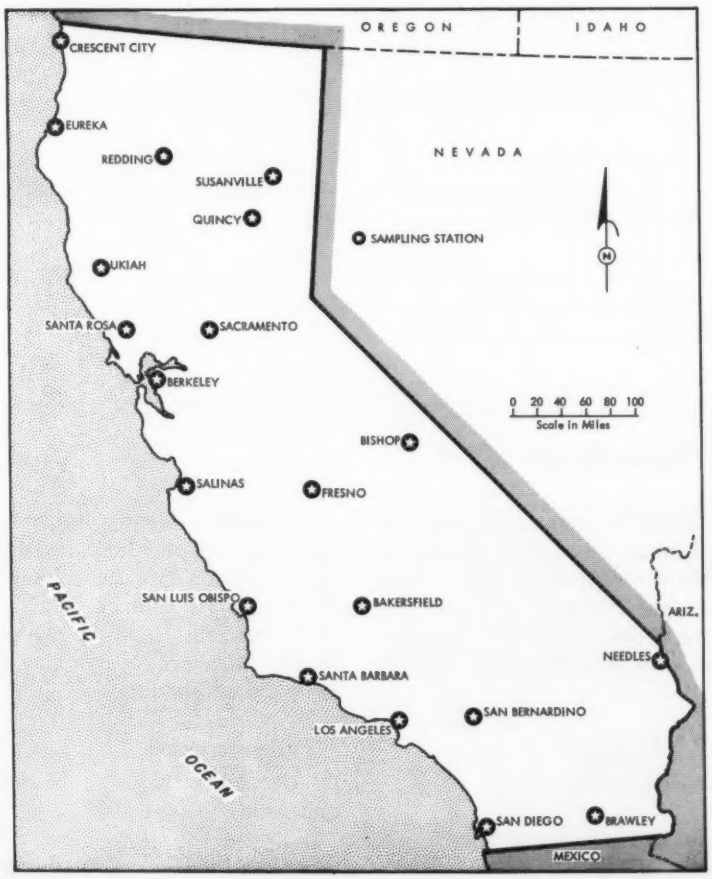

Figure 1. California diet sampling stations

Table 1. Estimated daily intake of radionuclides in California diets[a], October–December 1968

City	Consumption (kg/capita-day)[b]	Intake (pCi/capita-day)				Intake (g/capita-day)		
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Cs	K[c]	Na	Ca
Bakersfield	2.07	0	4	0.8	27	3.0	3.8	1.1
Berkeley	2.26	0	5	1.1	19	3.0	3.4	1.0
Bishop	1.41	0	4	.9	12	2.2	2.3	.8
Brawley	2.09	0	7	1.3	11	2.9	3.9	1.2
Crescent City	2.32	0	13	1.4	42	3.4	3.8	.9
Eureka	2.35	0	7	1.4	24	2.8	4.3	.9
Fresno	NS							
Los Angeles	1.60	0	5	1.1	19	2.1	2.9	.6
Needles	2.15	0	5	1.1	20	2.8	3.2	.9
Quincy	2.12	0	34	2.9	17	3.5	3.4	1.6
Redding	2.34	[d]3.1	4	1.3	11	3.2	3.0	.8
Sacramento	2.35	0	6	1.2	12	2.7	4.4	1.0
Salinas	2.25	[d]1.5	4	1.1	17	3.2	4.9	.8
San Bernardino	1.47	[d]3.7	4	.9	12	2.2	3.5	.8
San Diego	1.52	0	5	.7	15	2.5	2.4	.9
San Luis Obispo	1.96	0	5	1.8	14	3.5	4.4	1.4
Santa Barbara	1.88	0	5	1.2	16	2.2	2.9	.8
Santa Rosa	1.75	0	4	.7	11	2.2	2.2	1.1
Susanville	1.91	0	4	.8	17	2.4	3.2	.8
Ukiah	1.86	[d]2.2	4	2.0	20	3.0	3.3	1.2

[a] Based on analyses of Hospital Standard Diets located in listed cities. Zirconium-95, manganese-54, and cerium-141, -144, were zero during this period.
[b] Kilograms of food per person per day in this diet.
[c] Natural potassium contains 0.0119 percent of radioactive potassium-40.
[d] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported in the best available estimate, but is not statistically significant.
NS, no sample.

Table 2. Estimated daily intake of radionuclides in California diets[a], January–March 1969

City	Consumption (kg/capita-day[b])	Intake (pCi/capita-day)				Intake (g/capita-day)		
		^{89}Sr[c]	^{90}Sr	^{226}Ra	^{137}Cs	K[d]	Na	Ca
Bakersfield	2.25	0	7	0.2	8	3.1	5.7	1.3
Bishop	1.62	0	7	1.0	9	2.4	2.8	1.2
Brawley	2.30	0	8	1.4	10	3.4	4.4	1.1
Crescent City	2.52	0	15	.6	22	3.4	4.3	1.6
Eureka	2.25	0	6	.8	18	2.7	4.2	.7
Fresno	2.33	0	7	1.1	10	3.7	3.8	1.4
Los Angeles	1.90	0	5	1.1	19	2.3	3.2	.5
Needles	2.34	0	6	.4	7	2.9	3.0	1.0
Quincy	2.15	0	6	.7	15	3.0	3.0	.7
Redding	2.36	0	11	.9	18	2.7	3.1	2.1
Sacramento	2.53	0	8	1.4	15	3.2	5.0	1.3
Salinas	2.49	0	6	1.2	8	3.3	5.6	.8
San Bernardino	1.93	0	11	1.4	15	3.0	4.2	1.1
San Diego	2.35	0	6	1.2	15	3.6	3.9	1.2
San Luis Obispo	2.08	0	7	1.6	14	3.1	4.3	1.2
Santa Barbara	2.20	0	14	1.7	11	2.7	3.1	1.8
Santa Rosa	1.82	0	7	1.5	9	2.1	3.0	1.2
Susanville	1.87	0	4	.8	15	2.6	2.7	.9
Ukiah	1.92	0	15	2.3	10	2.9	3.5	1.2

[a] Based on analyses of Hospital Standard Diets located in listed cities. Zirconium-95, manganese-54, and cerium-141, -144, were zero during this period.
[b] Kilograms of food per person per day in this diet.
[c] Practical reporting levels are: strontium-89, 2 pCi/capita-day; zirconium-niobium-95, 7 pCi/capita-day; manganese-54, 7 pCi/capita-day; cerium-141–144, 10 pCi/capita-day.
[d] Natural potassium contains 0.0119 percent of radioactive potassium-40.

Radiation Laboratory of the State Department of Public Health. Accompanying each sample is a record prepared by the dietitians indicating the types and quantities of food included.

Analytical procedures

After being weighed at the laboratory, each sample is homogenized and analyzed for gamma-ray emitters, then dried and ashed prior to analysis for strontium-89, strontium-90, radium-226, stable calcium, and sodium.

Data and discussion

The resultant estimates of daily intake of radionuclides in the California diets are given in table 1 (October–December 1968), table 2 (January–March 1969).

It should be noted that levels of radioactivity were observed to be far below those levels for which consideration should be given to protective health action. A summary of strontium-90 and cesium-137 intake trends in California diets from January 1964 through March 1969 is given in figures 2 and 3.

REFERENCE

(1) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH, BUREAU OF RADIOLOGICAL HEALTH. Radiol Health News 4:4 (October 1965). 2151 Berkeley Way, Berkeley, Calif., 94704.

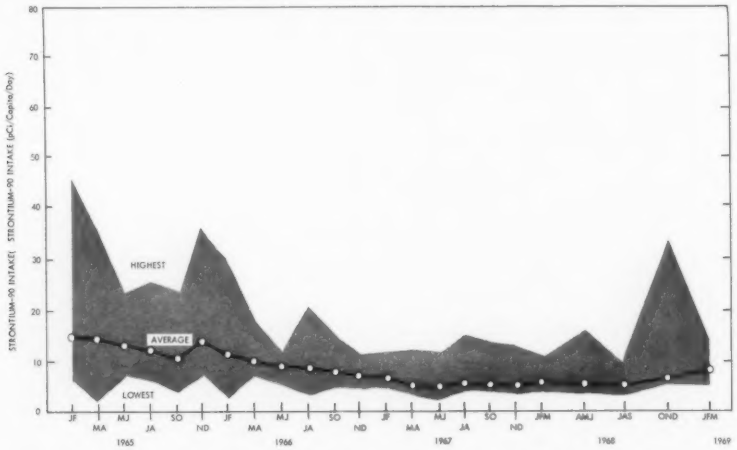
STRONTIUM-90 INTAKE(STRONTIUM-90 INTAKE (pCi/Caplte/Day)
HIGHEST
AVERAGE
LOWEST
JF MA MJ JA SO ND JF MA MJ JA SO ND JF MA MJ JA SO ND JFM AMJ JAS OND JFM
1965 1966 1967 1968 1969

Figure 2. Averages and ranges of daily strontium-90 intake in California diets, 1965–March 1969

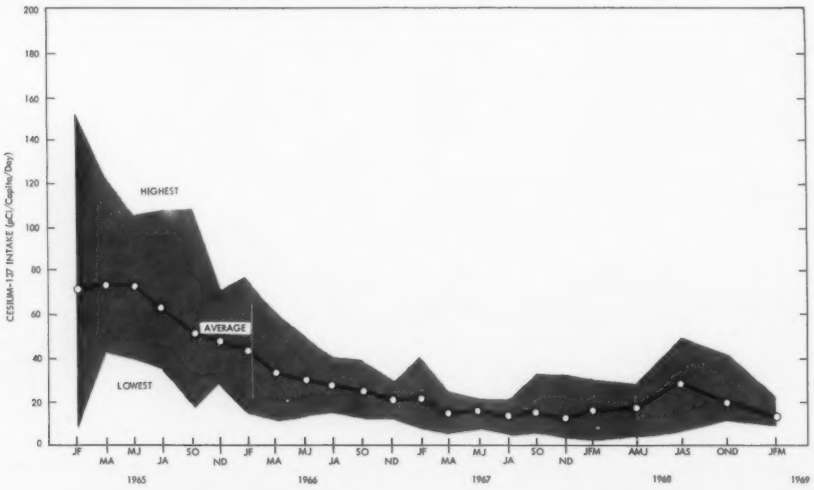
CESIUM-137 INTAKE (pCi/Caplte/Day)
HIGHEST
AVERAGE
LOWEST
JF MA MJ JA SO ND JF MA MJ JA SO ND JF MA MJ JA SO ND JFM AMJ JAS OND JFM
1965 1966 1967 1968 1969

Figure 3. Averages and ranges of daily cesium-137 intake in California diets, 1965–March 1969

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–October 1967	May 1968
November–December 1967, and January–September 1968	May 1969

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Water sampling program	Period reported	Issue
California	January–June 1968	December 1969
Colorado River Basin	1967	December 1968
Minnesota	January–June 1969	January 1970
New York	July–December 1968	September 1969
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	July–December 1968	November 1969
Washington	July 1967–June 1968	June 1969

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation	April–June 1968	October 1969

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1. Radiation Alert Network January 1970

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during January 1970. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, January 1970

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Number of samples	Precipitation			
			Maximum	Minimum	Average[a]			Total depth (mm)	Field estimation of deposition		
									Number of samples	Depth (mm)	Total deposition (nCi/m³)
Ala:	Montgomery	20	3	0	1	Dec 69	5	90	5	90	63
Alaska:	Adak	[b]				Dec 69	[c]				
	Anchorage	19	0	0	0	Aug 69	[c]				
	Attu Island	5	4	0	1	Jan 70	[c]				
	Fairbanks	20	1	0	0	Sept 69	3	6	3	6	2
	Juneau	[b]				Oct 69	[c]				
	Kodiak	[b]				Nov 69	[c]				
	Nome	2	1	1	1	Mar 70	[c]				
	Point Barrow	[b]				Feb 70	[c]				
	St. Paul Island	[b]				Apr 70	[c]				
Ariz:	Phoenix	20	14	3	9	Oct 69	[c]				
Ark:	Little Rock	9	3	0	0	Aug 69	[c]				
Calif:	Berkeley	21	1	0	0	Nov 69	10	250	10	250	0
	Los Angeles	21	3	0	1	Mar 70	[c]				
C.Z:	Ancon	16	1	0	0	Nov 69	[c]				
Colo:	Denver	20	7	1	2	Nov 69	[c]				
Conn:	Hartford	20	0	0	0	Sept 69	5	20	5	20	0
Del:	Dover	20	1	0	0	May 70	[c]				
D.C:	Washington	23	2	0	0	Feb 70	[c]				
Fla:	Jacksonville	12	0	0	0	Aug 69	4	79	4	32	11
	Miami	18	0	0	0	Sept 69	4	58	4	58	0
Ga:	Atlanta	21	1	1	1	Apr 70	1	80	1	80	40
Guam:	Agana	[b]				May 70	[c]				
Hawaii:	Honolulu	22	1	0	0	Jan 70	3	32	[d]		
Idaho:	Boise	21	1	0	0	Jan 70	14	122	14	122	25
Ill:	Springfield	17	1	0	0	Feb 70	[c]				
Ind:	Indianapolis	[b]				Apr 70	[c]				
Iowa:	Iowa City	20	1	0	0	Nov 69	1	11	1	11	0
Kans:	Topeka	20	3	0	1	Aug 69	1	4	1	4	0
Ky:	Frankfort	9	4	1	2	Feb 70	[c]				
La:	New Orleans	13	1	0	0	Feb 70	5	109	[d]		
Maine:	Augusta	21	0	0	0	Mar 70	6	20	6	20	0
Md:	Baltimore	20	1	0	0	Sept 69	3	13	3	13	0
	Rockville	12	2	0	1	Jan 70	[c]				
Mass:	Lawrence	19	0	0	0	May 70	2	10	2	10	0
	Winchester	21	1	0	0	Dec 69	4	17	4	17	0
Mich:	Lansing	18	0	0	0	Jan 70	[c]				
Minn:	Minneapolis	21	0	0	0	May 70	2	5	2	5	1
Miss:	Jackson	16	1	0	0	Mar 70	1	8	1	8	0
Mo:	Jefferson City	20	1	0	0	Apr 70	1	3	1	3	0
Mont:	Helena	21	7	0	1	Dec 69	1	5	1	5	0
Nebr:	Lincoln	13	5	0	1	Apr 70	[c]				
Nev:	Las Vegas	12	6	0	1	Sept 69	[c]				
N.H:	Concord	[b]				Feb 70	[c]				
N.J:	Trenton	21	0	0	0	Mar 70	4	17	4	17	0
N. Mex:	Santa Fe	18	2	0	1	Dec 69	[c]				
N.Y:	Albany	2	1	0	0	Apr 70	1	7	1	7	4
	Buffalo	22	0	0	0	Nov 69	[c]				
	New York City	19	1	0	0	Dec 69	[c]				
N.C:	Gastonia	16	6	1	2	Nov 69	3	17	[d]		
N. Dak:	Bismarck	21	1	0	0	Feb 70	6	8	6	8	0
Ohio:	Cincinnati	[b]				May 70	[c]				
	Columbus	2	0	0	0	Mar 70	[c]				
	Painesville	18	0	0	0	Sept 69	6	17	6	17	7
Okla:	Oklahoma City	19	4	0	1	Jan 70	1		1	7	0
	Ponca City	21	4	0	2	Sept 69	[c]				
Ore:	Portland	[b]				Apr 70	[c]				
Pa:	Harrisburg	16	0	0	0	Apr 70	3	25	3	25	7
P.R:	San Juan	[b]				Mar 70	[c]				
R.I:	Providence	10	1	0	0	Jan 70	[c]				
S.C:	Columbia	15	5	0	1	Dec 69	5	64	5	64	4
S. Dak:	Pierre	2	2	1	2	Oct 69	[c]				
Tenn:	Nashville	20	1	0	0	Jan 70	3	25	3	24	0
Tex:	Austin	4	8	2	4	May 70	[c]				
	El Paso	[b]				Feb 70	[c]				
Utah:	Salt Lake City	31	2	0	1	Mar 70	6	16	6	16	2
Vt:	Barre	16	1	0	0	Aug 69	2	5	2	5	1
Va:	Richmond	20	1	0	0	Aug 69	3	16	3	16	3
Wash:	Seattle	16	0	0	0	Aug 69	12	159	[d]		
	Spokane	21	0	0	0	May 70	[c]				
W. Va:	Charleston	19	2	0	1	Dec 69	6	23	6	23	2
Wisc:	Madison	21	0	0	0	Aug 69	5	15	5	13	2
Wyo:	Cheyenne	17	3	0	1	Sept 69	1	22	1	22	7
Network summary		1,030	14	0	1		4	38	4	32	6

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samp es received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

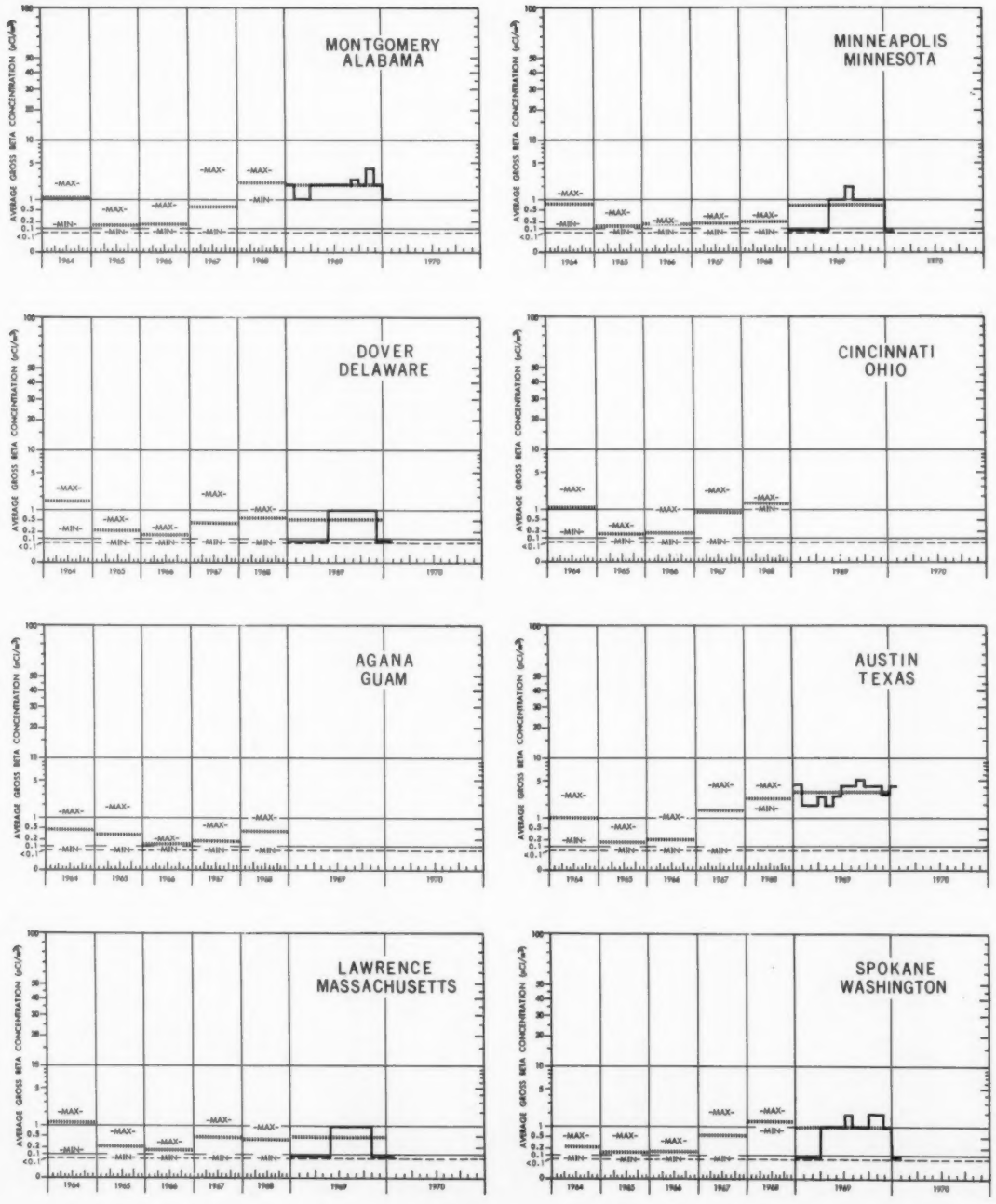

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1964–January 1970

2. Canadian Air and Precipitation Monitoring Program[1], January 1970

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for January 1970 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, January 1970

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.2	0.0	0.1	11	0.1
Coral Harbour	13	.1	.0	.1	527	1.7
Edmonton	31	.1	.0	.1	24	.4
Ft. Churchill	30	.1	.0	.1	21	.2
Fredericton	30	.1	.0	.1	12	.2
Goose Bay	30	.1	.0	.0	12	.4
Halifax	31	.2	.0	.1	8	.3
Inuvik	31	.1	.0	.1	90	.6
Montreal	31	.1	.0	.1	52	1.0
Moosonee	31	.1	.0	.1	12	.3
Ottawa	31	.1	.0	.1	16	.5
Quebec	31	.1	.0	.1	16	.7
Regina	31	.1	.0	.1	18	.3
Resolute	30	.1	.0	.1	35	.1
St. John's, Nfld.	30	.1	.0	.0	7	.5
Saskatoon	31	.1	.0	.1	37	.3
Sault St. Marie	31	.1	.0	.1	25	1.7
Thunder Bay[a]	31	.1	.0	.1	18	.8
Toronto	31	.2	.0	.1	42	1.2
Vancouver	31	.1	.0	.0	21	2.2
Whitehorse	31	.1	.0	.0	26	.4
Windsor	31	.1	.0	.1	39	1.5
Winnipeg	31	.1	.0	.1	27	.6
Yellowknife	30	.1	.0	.1	32	.3
Network summary	720	0.2	0.0	0.1	47	0.7

[a] Effective January 1, 1970, the City of Fort William officially changed its name to Thunder Bay.

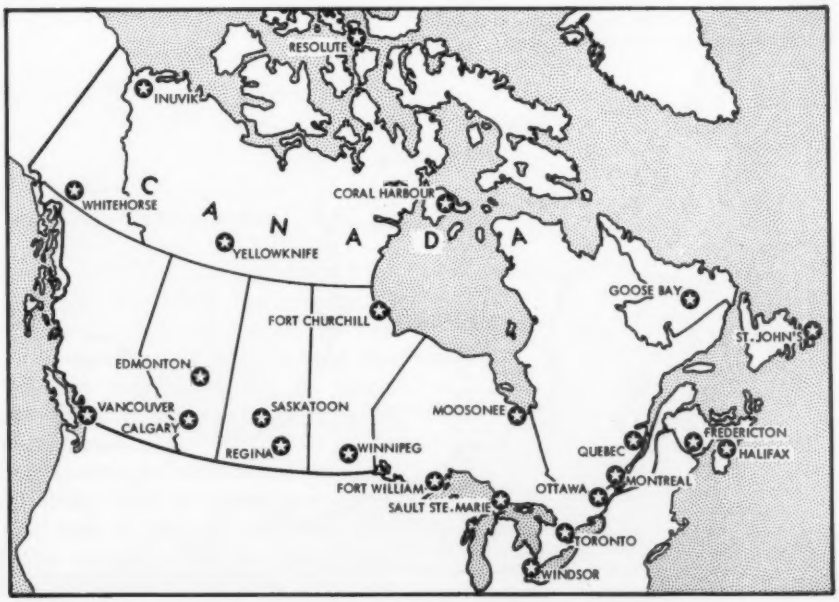

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program November 1969

National Commission of Nuclear Energy
México, D.F.

The Radiation Surveillance Network of México was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6 by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month was needed to get a reliable average radioactivity at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during November 1969 is presented in table 3.

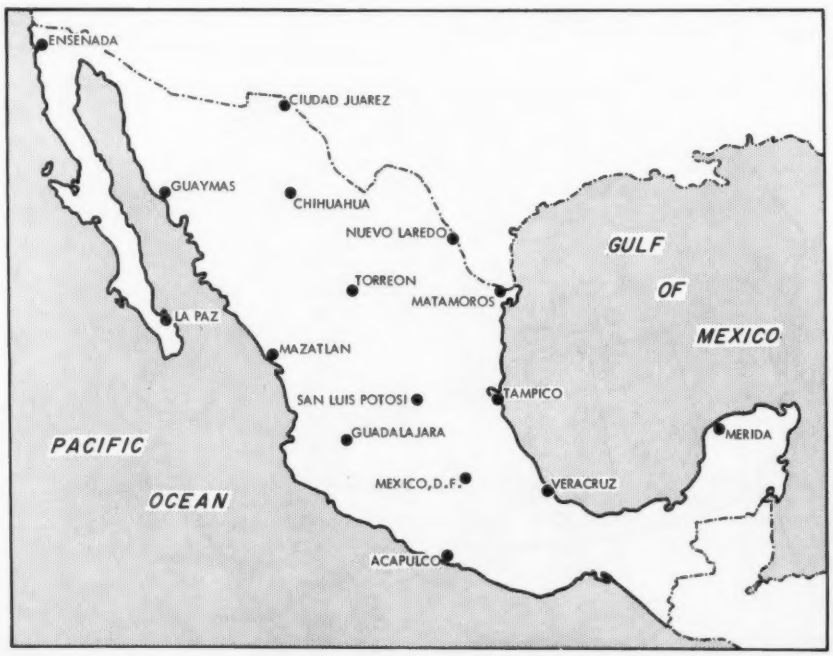

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, November 1969

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	9	0.1	<0.1	0.1
Chihuahua	12	.3	.1	.1
Ciudad Juarez	NS			
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	15	.2	.1	.1
Matamoros	NS			
Mazatlan	NS			
Mérida	4	.2	<.1	.2
México, D.F.	7	.1	<.1	.1
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	10	.3	.1	.2
Veracruz	NS			

NS, no sample, station temporarily shutdown.

Figure 5. Pan American Sampling Program stations

4. Pan American Air Sampling Program January 1970

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The January 1970 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, January 1970

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Argentina:				
Buenos Aires	16	0.17	0.02	0.09
Bolivia:				
La Paz	10	.08	.00	.03
Chile:				
Santiago	27	.24	.03	.09
Colombia:				
Bogota	19	.05	.00	.02
Ecuador:				
Cuenca	NS	NS	NS	NS
Guayaquil	18	.07	.02	.04
Quito	NS	NS	NS	NS
Guyana:				
Georgetown	NS	NS	NS	NS
Jamaica:				
Kingston	8	.13	.03	.07
Peru:				
Lima	17	.16	.05	.08
Venesuela:				
Caracas	10	.15	.00	.07
West Indies:				
Trinidad	18	.06	.02	.04
Pan American summary	143	0.24	0.00	0.06

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

XUM

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*6*) VASQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la República Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiologica (1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, April-June 1969[1]

Bureau of Radiological Health
U.S. Public Health Service

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

[1] Period during which death or surgical procedure occurred.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Bureau of Radiological Health at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

Figure 1. Georgraphical regions for human bone sampling

Table 1. Strontium-90 in human bone, April–June 1969

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Northeast:						
New Jersey	V	1	F	70.9± 7.5	17.3	4.09
New York	V	5	F	77.0± 7.9	27.7	2.77
Pennsylvania	V	6	F	65.3± 7.0	27.7	2.35
New York	V	8	F	84.3±10.0	34.2	2.46
	V	11	M	76.3± 6.9	29.4	2.59
	V	13	M	40.4± 5.3	13.8	2.92
	V	13	M	79.9± 8.3	42.6	1.87
	V	15	M	87.8± 9.7	38.4	2.28
	V	17	M	105.0±10.0	48.4	2.16
Vermont	V	17	M	80.5± 9.3	52.7	1.52
	V	18	F	114.0±12.0	56.7	2.01
	V	18	M	148.0±12.0	47.4	3.12
New York	V	18	M	87.8± 7.9	48.2	1.82
	V	19	M	53.4± 5.7	25.4	2.10
Vermont	V	20	M	73.9± 6.7	46.9	1.57
	V	20	M	120.0± 9.9	54.0	2.22
New York	V	21	M	87.8± 9.7	54.5	1.61
Massachusetts	V	22	F	203.0±18.0	68.4	2.96
New York	V	22	M	106.0±13.0	45.7	2.31
Southeast:						
South Carolina	V	1	M	102.0±12.0	29.1	3.50
Maryland	V	2	M	94.1±10.0	33.9	2.77
	V	5	F	63.1± 9.8	30.7	2.05
South Carolina	V	8	F	149.0±11.0	39.8	3.74
Maryland	V	9	M	68.4± 8.5	27.2	2.51
South Carolina	V	9	F	113.0± 9.7	32.6	3.46
Maryland	V	10	M	78.5±10.0	35.9	2.18
	V	10	M	63.6± 9.7	36.4	1.74
South Carolina	V	11	F	161.0±15.0	57.2	2.81
Georgia	V	11	M	126.0± 9.2	31.0	4.06
South Carolina	V	12	M	166.0± 9.9	40.6	4.08
	V	13	M	88.0± 8.5	39.7	2.21
Maryland	V	14	F	123.0±12.0	52.8	2.32
South Carolina	V	15	F	130.0±13.0	48.4	2.68
Maryland	V	15	F	104.0±12.0	47.6	2.18
	V	15	M	135.0±13.0	55.7	2.42
South Carolina	V	15	M	151.0±10.0	45.9	3.28
Maryland	V	16	M	110.0±10.0	47.9	2.29
	V	16	M	80.9±10.0	45.3	1.78
Georgia	V	17	F	111.0±10.0	46.5	2.38
Maryland	V	17	M	116.0± 9.1	49.5	2.34
	V	18	M	147.0±12.0	62.7	2.34
South Carolina	V	18	F	130.0± 9.1	45.8	2.83
	V	18	M	174.0±12.0	48.6	3.58
	V	18	M	107.0± 9.3	48.5	2.20
Maryland	V	18	M	109.0±11.0	52.5	2.07
	V	18	M	168.0±14.0	62.7	2.67
South Carolina	V	18	M	101.0±10.0	47.4	2.13
Maryland	V	19	M	93.1±10.0	63.0	1.47
	V	19	M	81.7±10.0	46.3	1.76
	V	19	M	53.3± 6.3	50.3	1.05
	V	19	F	108.0±11.0	50.6	2.13
	V	20	M	130.0± 9.5	53.3	2.43
	V	20	F	73.1±10.0	51.5	1.41
	V	20	M	110.0±10.0	67.9	1.62
	V	20	M	160.0±12.0	61.1	2.61
	V	20	M	120.0±15.0	58.2	2.06
	V	20	M	95.1± 9.5	50.2	1.89
	V	20	M	88.5±10.0	57.3	1.54
	V	20	M	86.1± 9.7	52.5	1.64
	V	21	M	114.0±12.0	52.0	2.19
	V	21	M	90.9± 9.8	57.9	1.56
	V	22	M	156.0±14.0	55.3	2.82
	V	22	M	106.0±11.0	56.3	1.88
	V	22	M	75.9±10.0	50.3	1.50
	V	22	M	129.0±13.0	53.3	2.42
	V	23	M	172.0±13.0	59.7	2.88
	V	23	F	89.1±11.0	42.8	2.08
	V	23	M	222.0±18.0	66.8	3.32
	V	23	F	103.0±12.0	48.6	2.11
	V	24	M	74.5±11.0	44.2	1.68
	V	24	M	80.4±9.5	44.1	1.82
	V	24	M	10.4± 1.3	45.8	.22
	V	25	M	132.0±12.0	54.6	2.41
Central:						
Wisconsin	V	1	M	51.8± 6.7	31.6	1.63
Ohio	V	2	M	65.7±10.0	30.6	2.14
	V	3	F	36.0± 6.3	21.8	1.65
	V	3	F	74.3± 8.7	32.2	2.30
	V	4	M	98.7±11.0	33.8	2.92
	V	4	M	38.9± 5.2	27.9	1.39
Wisconsin	V	5	M	103.0± 9.1	31.5	3.26
Michigan	V	10	F	83.3± 7.8	46.7	1.78
Ohio	V	11	M	67.5± 9.7	41.4	1.63
	V	11	F	59.5± 7.9	42.9	1.38
	V	12	M	88.1± 8.2	48.1	1.83
Wisconsin	V	13	M	52.4± 6.9	31.3	1.67
Ohio	V	14	M	77.9± 7.0	35.3	2.20
	V	15	M	142.0±10.0	55.0	2.58
	V	16	M	113.0±10.0	57.7	1.95
	V	16	M	90.5± 7.6	41.6	2.17

See footnotes at end of table.

Table 1. Strontium–90 in human bone, April–June 1969—Continued

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium–90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Iowa	V	16	M	98.0± 8.8	53.5	1.83
	V	16	M	116.0±11.0	52.3	2.21
	V	17	M	154.0±15.0	58.7	2.62
	V	17	M	113.0±11.0	65.2	1.73
	V	18	F	119.0± 9.8	48.0	2.47
	V	18	M	107.0±10.0	47.4	2.25
	V	18	M	44.5± 8.3	50.6	.87
Michigan	V	19	F	103.0±13.0	56.6	1.81
Iowa	V	20	F	225.0±18.0	57.5	3.91
Ohio	V	20	M	80.7± 8.7	53.7	1.50
Nebraska	V	20	M	82.8± 7.2	46.2	1.79
Ohio	V	22	F	103.0± 8.6	46.0	2.23
	V	22	M	73.1± 9.7	59.3	1.23
	V	24	M	52.3± 7.1	47.9	1.09
Delta:						
Louisiana	R	8	M	154.0±13.0	45.5	3.38
Northwest:						
Washington	V, I	1	M	64.6± 9.1	27.2	2.37
Northwest:						
Oregon	V	5	F	53.2± 7.9	30.5	1.74
	V	6	F	76.1± 9.8	55.2	1.37
Washington	V	13	M	66.4± 7.3	36.6	1.81
Oregon	V	16	M	56.8± 6.0	39.2	1.44
	V	17	M	77.8±10.0	45.7	1.70
	V	18	M	101.0± 7.3	39.9	2.53
	V	19	F	83.7±10.0	64.4	1.29
	V	21	F	58.1± 6.3	42.8	1.35
	V	22	F	78.3± 9.9	49.3	1.58
	V	22	M	60.6± 6.5	28.5	2.12
	V	24	M	67.9±10.0	46.1	1.47
	V	25	F	69.3±11.0	54.1	1.28
Southwest:						
Texas	V	1	M	149.0±13.0	32.7	4.55
	V	4	F	63.8± 6.8	30.1	2.11
Colorado	V	17	M	78.0± 7.2	42.6	1.83
	V	18	F	132.0±14.0	58.1	2.27
	V	20	M	114.0±11.0	54.1	2.10
	V	20	F	72.2± 9.4	56.9	1.26
	V	21	M	94.3±13.0	50.4	1.87
California	T	21	M	112.0±10.0	105.0	1.06
Colorado	V	21	M	82.1± 9.4	46.9	1.75
	V	23	M	61.2± 6.7	48.4	1.26
California	V	23	M	14.0± 6.3	39.9	.35
Texas	V	23	F	65.1± 9.5	47.8	1.36
Colorado	V	25	M	69.8±10.0	57.4	1.21
North:						
Alaska	V	1	M	88.1±10.0	29.7	2.96
	V	1	F	94.5±10.0	27.4	3.44
	V	5	F	58.7± 8.1	34.0	1.72
	R	14	M	225.0±34.0	139.0	1.61
	R	22	F	188.0±31.0	133.0	1.41

[a] V, vertebrae; R, rib; I, ilium; T, tibia.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

The analytical results for strontium-90 in individual bones from persons dying during the second quarter (April–June) of 1969 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

REFERENCES

(*1*) RIVERA, J. Strontium–90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium–90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64–1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium–90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*5*) HALLISEY, R. M., and M. A. WALL. Strontium–90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

(*6*) BARATTA, E. J., E. S. FERRI, and M. A. WALL. Strontium–90 in human bones in the United States, 1962–1966. Radiol Health Data Rep 11:183–186 (April 1970).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1968	September 1969
October–December 1968	December 1969
January–March 1969	March 1970

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Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Oak Ridge Area and the Savannah River Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Oak Ridge Area[2] January–June 1969

Union Carbide Nuclear Company
Oak Ridge, Tenn.

Oak Ridge area is a complex made up primarily of the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are concentrated by evaporation and disposed of in deep wells. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 1) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances from 12 to 75 miles (figure 2). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average radioactivity concentrations are presented in tables 1 and 2. Airborne radioactive iodine is monitored in the immediate environment of the plant areas by passing air through a cartridge containing activated charcoal.

During the January–June 1969 surveillance period, 234 samples were collected from perimeter monitoring stations and analyzed for iodine-131. Of these, the maximum concentration detected was 0.49 pCi/m^3, the minimum was less than 0.01 pCi/m^3, and the average was 0.02 pCi/m^3. The radiation protection standard specified in the AEC Manual for iodine-131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m^3.

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak

[2] Summarized from Environmental Levels of Radioactivity for the Oak Ridge Area, (Report Period, January–June 1969). Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

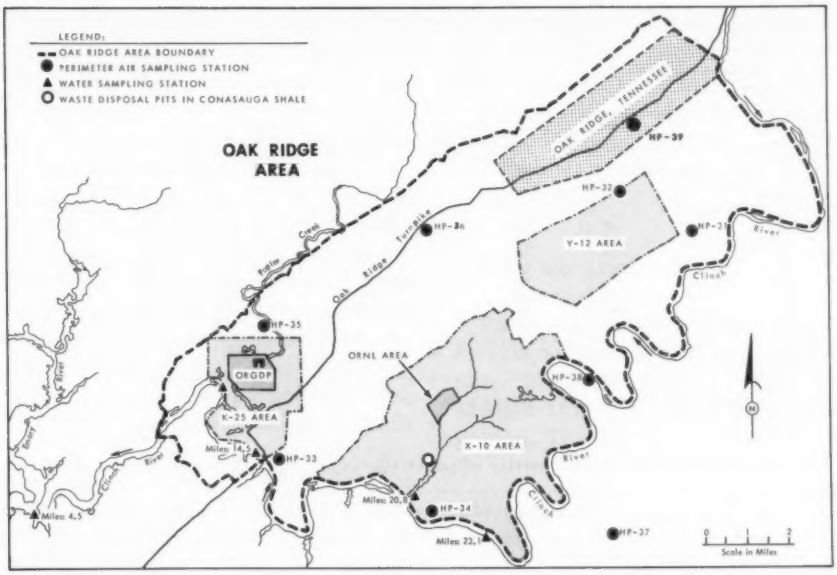

Figure 1. Oak Ridge Area—environmental sampling locations

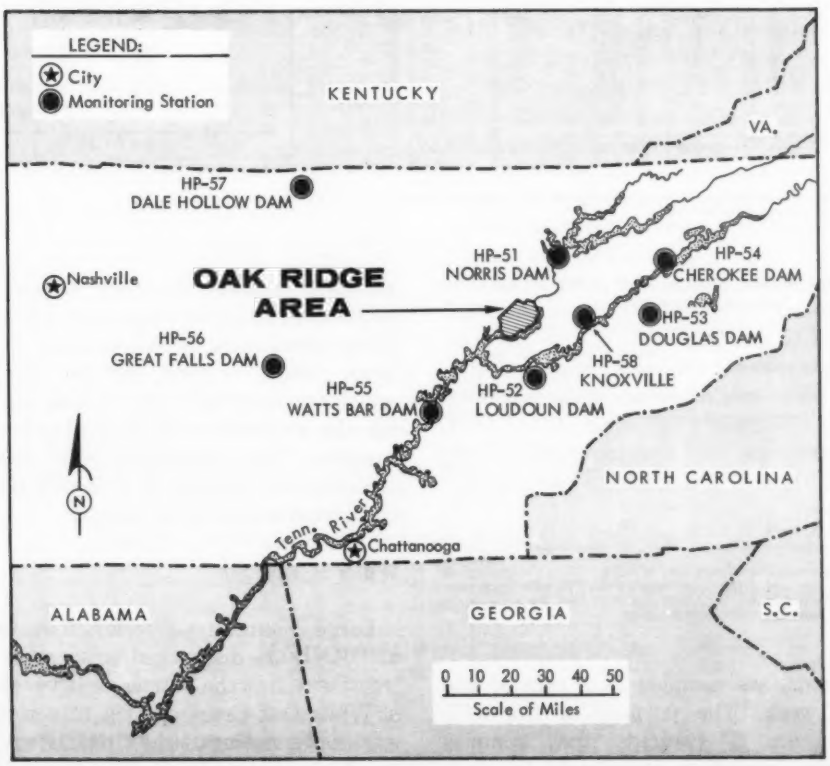

Figure 2. Remote air monitoring stations, Oak Ridge Area

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Table 1. Long-lived gross beta radioactivity of particulates in air, Oak Ridge Area, January–June 1969

Perimeter stations						Remote stations					
Station number (figure 1)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]	Station number (figure 2)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]
		Maximum	Minimum	Average				Maximum	Minimum	Average	
HP-31	26	0.38	0.011	0.15	0.15	HP-51	26	0.36	0.062	0.16	0.16
HP-32	26	.47	.029	.18	.18	HP-52	26	.44	.035	.16	.16
HP-33	26	.31	< .001	.13	.13	HP-53	26	.45	.041	.16	.16
HP-34	26	.59	.019	.16	.16	HP-54	25	.35	.024	.14	.14
HP-35	26	.45	.047	.16	.16	HP-55	26	.44	.003	.14	.14
HP-36	127[b]	.41	.051	.18	.18	HP-56	26	.45	.029	.16	.16
HP-37	26	.36	.017	.14	.14	HP-57	26	.43	.003	.16	.16
HP-38	26	.43	.039	.17	.17	HP-58	25	.44	.042	.18	.18
HP-39	26	.49	.027	.18	.18						
Summary	335	0.59	<0.001	0.16	0.16		206	0.45	0.003	0.16	0.16

[a] The applicable AEC Radiation Protection Standard is 100 pCi/m³.
[b] Sampling frequency—5 days per week.

Table 2. Long-lived gross alpha radioactivity of particulates in air, Oak Ridge Area, January–June 1969

Perimeter stations						Remote stations					
Station number (figure 1)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]	Station number (figure 2)	Number of samples	Concentration (pCi/m³)			Percent of AEC standard[a]
		Maximum	Minimum	Average				Maximum	Minimum	Average	
HP-31	26	0.005	<0.001	0.002	0.10	HP-51	26	0.004	<0.001	0.001	0.05
HP-32	26	.007	< .001	.002	.10	HP-52	26	.004	< .001	.001	.05
HP-33	26	.004	< .001	.001	.05	HP-53	26	.002	< .001	.001	.05
HP-34	26	.002	< .001	.001	.05	HP-54	25	.008	< .001	.001	.05
HP-35	26	.007	< .001	.002	.10	HP-55	26	.006	< .001	.001	.05
HP-36	127[b]	.008	< .001	.003	.15	HP-56	26	.002	< .001	.001	.05
HP-37	26	.005	< .001	.001	.05	HP-57	26	.002	< .001	.001	.05
HP-38	26	.002	< .001	.001	.05	HP-58	25	.005	< .001	.002	.10
HP-39	26	.003	< .001	.001	.10						
Summary	335	0.008	0.001	0.002	0.10		206	0.008	<0.001	0.001	0.05

[a] The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.
[b] Sampling frequency—5 days per week.

Table 3. Radionuclides in raw milk, Oak Ridge Area January–June 1969

Radionuclide and location	Concentration (pCi/liter)		
	Maximum	Minimum[a]	Average
Iodine-131:			
Immediate environs	25	<10	<10
Remote environs	<10	<10	<10
Strontium-90:			
Immediate environs	47	7	21
Remote environs	22	10	17

[a] The minimum detectable concentrations of iodine-131 and strontium-90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this concentration.

Ridge operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine-131 and strontium-90 detected in raw milk samples during the period are given in table 3.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged, after some preliminary treatment, into the Tennessee River system by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y-12 Plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that

resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river. Samples are analyzed for the long-lived beta-particle emitters, uranium, and the transuranic alpha-particle emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 4 for the period from January through June 1969.

Table 4. Concentrations of major radionuclides in the Clinch River, January–June 1969

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River[a]		
	Mile: 23.1 (Upstream)	Mile: 20.8[b] (Outfall)	Mile: 4.5 (Downstream)
Strontium-90	0.4	1.1	1.4
Cerium-144	.5	<.1	.4
Cesium-137	.8	.6	2.6
Ruthenium-106	1.2	.7	1.3
Cobalt-60	6.2	.5	6.3
Zirconium-niobium-95	.5	.1	.3
Gross beta	9.6	6.5	12.0

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River (figure 1).
[b] The concentrations at mile: 20.8 are not measured directly but the values are calculated based on the levels of waste released and the dilution provided by the river.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For these samples, the uranium concentrations were less than 1 pCi/liter, the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 20 nCi/liter.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 5.

Discussion of data

The average air contamination levels for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 1 and 2) was 0.16 percent of the AEC radiation protection standard for uncontrolled areas.

The average air contamination levels for gross alpha radioactivity, as shown by the continuous air monitoring filter data, for the immediate and remote environs of the plants were 0.10 percent and 0.05 percent, respectively, of the AEC radiation protection standard for natural uranium for uncontrolled areas.

The average concentration of iodine-131 in air in the immediate environs of the plants was 0.02 pCi/m^3. This is approximately 0.02 percent of the AEC radiation standard for uncontrolled areas.

The average concentrations of iodine-131 in raw milk in the immediate and remote environs of the Oak Ridge area were both less than 10 pCi/liter. These levels fall within the limits of FRC Range I

Table 5. External gamma radiation levels, Oak Ridge Area January–June 1969

Location	Radiation level (mR/h)						
	January	February	March	April	May	June	Average
Solway Gate	0.018	0.011	0.014	0.012	0.010	NA	0.013
Y-12, East Portal	.11	.10	.014	.012	.020	NA	.013
Newcomb Road	.013	.011	.016	.011	0.15	NA	.011
Gallaher Gate	.014	.013	.015	.013	.015	NA	.014
White Wing Gate	.012	.010	.018	.013	.012	NA	.013

[a] The background in the Oak Ridge area, determined in 1943, was approximately 0.012 mR/h.
NA, no analysis.

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if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentrations of strontium-90 in raw milk in the immediate and remote environs of the controlled areas were 21 pCi/liter and 17 pCi/liter, respectively. The average for the immediate environs, 21 pCi/liter, falls near the lower limit of FRC Range II and the value for the remote environs, 17 pCi/liter, falls within the limits of FRC Range I for transient rates of daily intake of strontium-90 for application to the average of suitable samples of an exposed population.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	June 1969
July–December 1968	January 1970

2. Savannah River Plant[3] January–June 1969

E. I. duPont de Nemours
Aiken, S.C.

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E. I. duPont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Ga. Production facilities include a fuel preparation area, three reactors, two fuel separation areas, and a heavy water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

The DuPont Environmental Monitoring Group has maintained a continuous monitoring program since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200 square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the AEC radiation protection standards as given in the AEC Manual.

Sensitive instruments, which can detect traces of radioactive materials far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity and atmospheric fallout are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by biweekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about a 25-mile radius from the center of the plant (figure 3). Deposition rates of radioactive material at each station were also determined by monthly analyses of rainwater ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne radioactivity by SRP would be detected

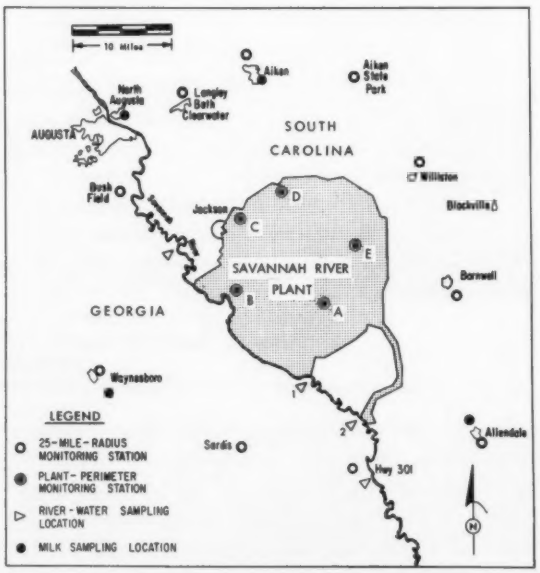

Figure 3. Environmental sampling locations Savannah River Plant

[3] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, January–June 1969" (DPST 69-30-2).

regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Ga., and at Columbia and Greenville, S. C., are so distant from SRP that the effect of SRP operations is negligible; they are reference points for determining background radioactivity levels (figure 4). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between fallout and SRP releases.

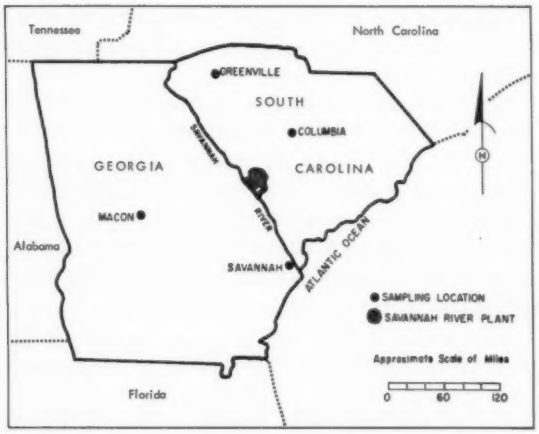

Figure 4. Distant air monitoring stations Savannah River Plant

The calculated average concentration of gross beta radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at mile 4.5 (near Kingston, Tenn.) were 6.5 pCi/liter and 12 pCi/liter, respectively. These values are 0.49 percent and 0.52 percent of the weighted average AEC radiation protection standards. The higher than normal average concentration reported for radioactivity at mile 23.1, Melton Hill Dam, was due primarily to cobalt-60. This contamination was found in the river upstream from the ORNL waste outfall and was the result of a source of contamination from a nuclear company upstream from Oak Ridge Operations. The average concentration of transuranic alpha-particle emitters in the Clinch River at mile 20.8 was 0.011 pCi/liter which is 0.01 percent of the AEC radiation protection standard for natural uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.013 mR/h, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

A release of airborne ruthenium-103 and plutonium-238 during a 2-week period in April from a separations area, near the center of the plant, was evident at air monitoring stations near the plant perimeter. Ruthenium-103 concentration in air averaged 0.16 pCi/m³ at the 25-mile radius stations (March 28–April 10), the maximum concentration was 0.21 pCi/m³ at Langley. Ruthenium-103 at the plant perimeter averaged 0.22 pCi/m³ (March 28–April 14). The AEC standard for ruthenium-103 in air for the general population is 3,000 pCi/m³. Although plant-released plutonium-238 could not be detected and identified beyond the manufacturing areas by gross alpha counting of routine air filters, chemical separation of the alpha-particle emitters on the filter papers, followed by low-level counting and spectrometry, showed that plutonium-238 was detectable at the plant boundary by special techniques. The plutonium-238 percentage of the total plutonium radioactivity was slightly higher than that previously measured in surface air samples exposed only to fallout. The plutonium-238 was not detectable on the sample filters at 25 and 100 miles from the plant even by the special separation and counting procedures.

Curium-244 levels showed an increase for a brief period in June at one monitoring station near the plant boundary (location C, figure 3). Alpha radioactivity in air at the monitoring station near Jackson was 0.006 pCi/m³ for June 5 through June 13, compared to 0.0007 pCi/m³ for May 20–June 5. The AEC radiation protection standard for the general population is 0.3 pCi/m³. Increased deposition of alpha radioactivity also was measured at the location C monitoring station during June (0.19 nCi/m² as compared to about 0.008 at other locations). Release of more than the usual amount of curium-244 during a 10-minute period from a hot cell facility of the Savannah River Laboratory, combined with a northeasterly wind and a heavy rain, caused this localized condition.

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fult separation areas, was obscured by fallout excepe during the April releases of ruthenium-103. The influence of nuclear tests, which resumed in September 1961, is shown in figure 5. The present low levels of atmospheric activity are attributed to

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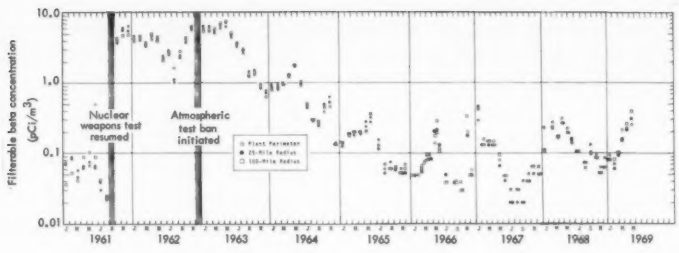

Figure 5. Influence of weapons tests

the moratorium on above-ground nuclear tests, which began in 1962. The observed spring increases are anticipated and result primarily from the mixing of the stratospheric debris into the troposphere. The average beta concentration in air increased from 0.09 to 0.16 pCi/m³ during the first half of 1969. Gamma-emitting radionuclides in fallout were cesium-134–137, cerium-141–144, ruthenium-103–106, and zirconium-niobium-95.

Radioactivity in air, determined from filter analyses, is shown in table 6. The January–June 1969 concentrations of filterable beta radioactivity (0.16 pCi/m³) and alpha radioactivity (0.0008 pCi/m³) in air were 0.16 and 1.1 percent of the respective AEC standards. Tritium oxide concentrations in air at the plant perimeter and at the 25-mile stations did not exceed 0.2 percent of the AEC standard.

Deposition of fallout during January–June 1969 totaled 22 nCi/m² at the plant perimeter locations and 21 nCi/m² at 25-mile radius locations; comparable values for the last half of 1968 were 7 and 5 nCi/m². Increased deposition of zirconium-niobium-95 and strontium-89 was observed during this period. Deposition at each sampling location is presented in table 7.

Algae and fish in Savannah River

Fish, predominantly bream, and indigenous

Table 6. Radioactivity in air, Savannah River Plant, January–June 1969

Sampling points	Alpha radioactivity[a] (fCi/m³)			Nonvolatile beta radioactivity[b] (pCi/m³)			Specific radionuclides in composite samples (pCi/m³)					
	Maximum	Minimum	Average	Maximum	Minimum	Average	$^{89,90}Sr$	^{137}Cs	$^{141,144}Ce$	$^{103,106}Ru$	^{95}Zr–Nb	^{7}Be
Plant perimeter:												
A	1.6	0.5	0.8	0.30	0.06	0.15						
B	1.2	.3	.8	.33	.06	.16						
C	1.8	.4	1.0	.27	.06	.14	0.007	0.01	0.05	0.05	0.08	0.32
D	1.4	ND	.8	.28	.06	.18						
E	1.1	.4	.6	.28	.06	.15						
Average			0.8			0.16						
25-mile-radius:												
Aiken Airport	1.3	0.4	0.7	0.30	0.06	0.14						
Aiken State Park	.9	.4	.6	.30	.06	.14						
Allendale	1.0	.4	.7	.32	.07	.15						
Barnwell	1.2	.3	.7	.30	.05	.14						
Bush Field	1.1	.3	.6	.28	.06	.13	.007	.007	.04	.05	.07	.26
Langley	1.0	.4	.7	.34	.06	.16						
Sardis	.9	.3	.6	.33	.06	.15						
Waynesboro	1.3	.4	.7	.31	.06	.15						
Williston	1.4	.3	.7	.34	.06	.16						
Highway 301	1.3	.3	.6	.32	.01	.14						
Average			0.7			0.15						
Distant air-monitoring:												
S.C.												
Columbia	2.8	ND	1.1	0.44	0.01	0.16						
Greenville	2.3	ND	1.0	.46	.05	.16						
Ga.												
Macon	1.2	ND	.7	.48	.02	.17	.007	.007	.04	.04	.08	.21
Savannah	1.7	ND	.9	.41	.05	.17						
Average			0.9			0.16						

[a] AEC radiation protection standard—70 fCi/m³; sensitivity of analysis—0.3 fCi/m³.
[b] AEC radiation protection standard—100 pCi/m³; sensitivity of analysis—0.006 pCi/m³.

Table 7. Total fallout deposited, Savannah River Plant, January–June 1969

Sampling points	Alpha (pCi/m²)	Radioactivity concentrations (nCi/m²)						
		Strontium–89	Strontium–90	Cesium–137	Cerium–141, –144	Zirconium–niobium–95	Beryllium–7	Ruthenium–103, –106
Plant perimeter:								
A	28	3.1	0.5	1.0	4.3	6.3	23.2	0.9
B	23	3.4	.6	1.2	6.0	5.8	26.8	1.1
C	192	3.2	.7	1.2	6.5	8.4	26.0	3.0
D	44	4.0	.7	1.5	8.8	10.0	41.6	4.1
E	35	3.2	.6	1.4	7.1	8.0	41.1	2.5
Average	64	3.6	.6	1.3	6.6	7.7	31.8	2.4
25-mile-radius:								
Aiken Airport	19	2.7	.8	1.1	6.8	7.5	25.4	2.6
Aiken State Park	26	2.4	.6	1.6	6.9	9.6	30.1	2.0
Allendale	29	2.0	.5	.7	3.9	3.2	19.1	.7
Barnwell	10	1.7	.5	.8	4.9	6.3	23.7	1.5
Bush Field	22	1.8	.7	1.7	8.5	11.9	34.5	2.0
Langley	50	4.4	.9	1.9	10.1	13.4	46.5	4.4
Sardis	20	2.0	.5	1.4	7.0	10.0	29.6	2.5
Waynesboro	50	2.8	.8	1.4	6.0	6.8	35.7	2.0
Williston	20	2.3	.6	.8	3.7	3.4	13.8	
Highway 301	44	2.2	.6	1.3	10.2	10.6	33.5	1.7
Average	29	2.4	.7	1.3	6.8	8.3	29.2	2.0

algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected weekly upstream from, adjacent to, and downstream from the Savannah River Plant effluents. Determination of radionuclides in algae is important because algae concentrate most radionuclides and also because of the role of algae in the food chain of aquatic organisms. Beta-particle concentrations in algae and fish adjacent to and downstream from SRP indicate some minor contribution by SRP. Although measurably higher than similar material collected at the control station upstream from SRP effluents, the increase is of no biological significance.

Specific radionuclide analyses were made on algae and fish collected from the Savannah River. Radiocesium and radiostrontium were found consistently in river algae; whereas cerium-141, -144, chromium-51, zirconium-niobium-95, manganese-54, zinc-65, and cobalt-60 were detected less frequently. Radiostrontium (maximum, 24 pCi/g, wet weight) was detected in bone tissue of river fish, and radiocesium (maximum 7 pCi/g, wet weight) was detected in the flesh tissue. The maximum concentrations of phosphorus-32 detected in bone of river fish was 13 pCi/g; and the maximum phosphorus-32 in flesh of river fish was 27 pCi/g.

Water monitoring

The plant site is drained by five streams that flow several miles through the reservation before reaching the river (figure 6). In January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish drinking water, partially supplied from the Savannah River, to most of Beaufort County, South Carolina. Water is supplied through a new canal from the river at a location about 90 miles below the SRP. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand. The tritium concentrations in raw water collected from the Beaufort-Jasper Water Plant averaged <4 nCi/liter (0.1 percent of the AEC standard) during the January–June 1969 period. The annual radiation exposure of an individual in this population due to

Table 8. Radioactivity in public water supplies January–June 1969

Sampling points	Alpha radioactivity[a] (pCi/liter)	Nonvolatile beta radioactivity[b] (pCi/liter)
	April	April
Aiken	2.2	7
Allendale	.2	ND
Augusta	ND	ND
Barnwell	ND	4
Bath	2.2	8
Blackville	.4	ND
Clearwater	.2	4
Jackson	2.8	7
Langley	1.2	ND
New Ellenton	1.4	ND
North Augusta	2.5	6
Sardis	<.2	ND
Waynesboro	<.2	6
Williston	1.1	5
Average	1.1	5

[a] AEC radiation protection standard—10 pCi/liter, sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter, sensitivity of analysis—4.0 pCi/liter.
ND, nondetectable.

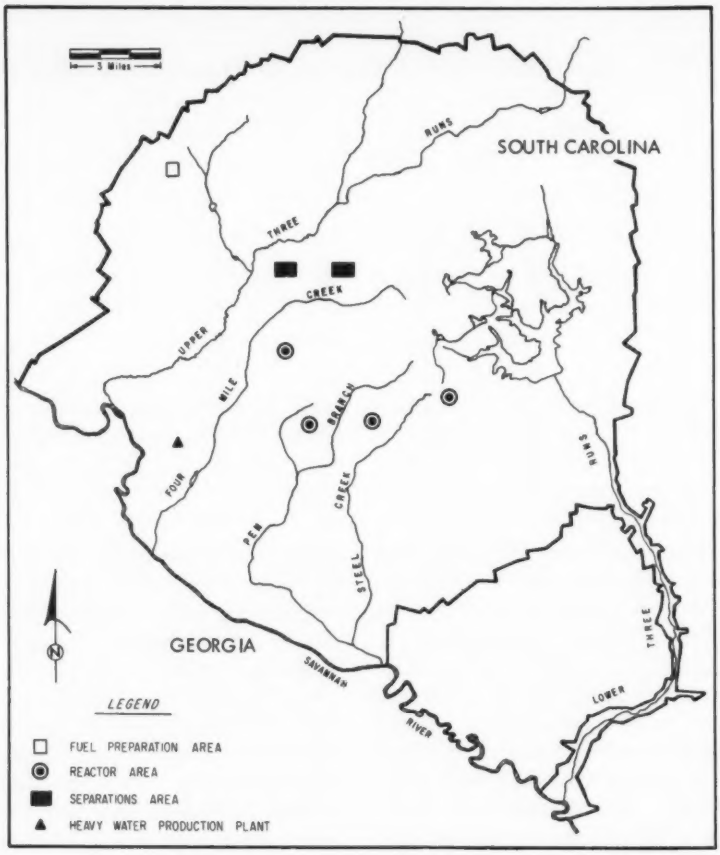

Figure 6. SRP production and effluent streams

the consumption of water containing this concentration of tritium is <0.7 mrem. This exposure may be compared with 40 mrem/a from natural potassium found in the human body or with the 170 mrem/a specified by the Federal Radiation Council as the annual dose guide for members of the public.

Communities near the plant get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed in April. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.1 pCi/liter) and beta radioactivity (5 pCi/liter) were essentially the same as those observed before plant startup. Radioactivity in public water supplies data are presented in table 8.

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 5. Concentrations of alpha and nonvolatile beta particle radioactivity in river water for the past year are presented in table 9. Average concentrations of specific radionuclides found in river water during January–June 1969 appear in table 10.

Tritium, sulfur-35, and trace amounts of cesium-137, strontium-89, and strontium-90 were the radionuclides of SRP origin detectable in river water at the downstream location. Strontium-90 and tritium from worldwide fallout were also detected in river water upstream from the Savannah plant.

Tritium, a beta-particle emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy-water

Table 9. Radioactivity in Savannah River water, July-December 1968 and January-June 1969

Sampling points	Alpha radioactivity[a] (pCi/liter)				Nonvolatile beta radioactivity[b] (pCi/liter)			
	January–June 1969			July–December 1968	January–June 1969			July–December 1968
	Maximum	Minimum	Average	Average	Maximum	Minimum	Average	Average
1 mile upstream from Upper Three Runs Creek (control)	0.6	ND	<0.2	<0.2	7	<4	<4	<4.0
Downstream from Steel Creek	.3	ND	< .2	< .2	11	<4	4	·5
Downstream from Lower Three Runs Creek	.5	ND	< .2	< .2	17	<4	7	11
8 miles downstream from Lower Three Runs Creek	.7	ND	< .2	< .2	13	<4	5	6

[a] AEC radiation protection standard—10 pCi/liter; sensitivity of analysis—0.2 pCi/liter.
[b] AEC radiation protection standard—3 nCi/liter; sensitivity of analysis—4.0 pCi/liter.
ND, nondetectable.

Table 10. Average concentration of radionuclides in Savannah River water January—June 1969

Radionuclides	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (3 miles upstream from plant)	Highway 301 (10 miles downstream from plant)	Percent AEC standard at Highway 301
Tritium	600	880	6,600	0.20
Ruthenium-103, 106	3.2	ND	ND	<.03
Cerium-141, 144	2.5	ND	ND	<.02
Cesium-134, 137	.6	ND	.5	.002
Neptunium-239	2.2	ND	ND	<.002
Barium-lanthanum-140	1.6	ND	ND	<.01
Zirconium-niobium-95	.5	ND	ND	<.001
Chromium-51	4.3	ND	ND	<.001
Strontium-89	.3	ND	.4	.01
Iodine-131	.5	ND	ND	<.16
Strontium-90	.01	.6	1.0	.33
Cobalt-60	1.4	ND	ND	<.005
Zinc-65	1.1	ND	ND	<.001
Manganese-54	.4	ND	ND	<.0004
Sulfur-35	5.0	ND	3.8	.006

ND, nondetectable, less than sensitivity of analysis.

moderator in the reactors. Chromium-51 and sulfur-35 (also a beta-particle emitter), the second and third most abundant radionuclides released to the river, are produced by neutron irradiation of stable chromium and stable sulfur. Tritium and chromium-51 are among the least dangerous of all radionuclides because neither concentrates in body tissues. The tritium, chromium-51 and sulphur-35 concentrations in river water averaged 0.20, <0.001 and 0.006 percent of the AEC radiation protection standards, respectively.

Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or sorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at seven other locations along a 25-mile radius route (these are not designated on figure 2). Bermuda grass was selected for analysis because of its importance as a pasture grass for dairy herds and its availability during all seasons of the year. Samples from each quadrant of the plant site and of the surrounding area were composited for monthly analysis. Gamma-emitting radionuclides in grass samples (excluding beryllium-7) were from fallout. Alpha-particle emitters averaged 0.2 pCi/g at the plant perimeter and 25-mile radius locations as compared to 0.1 pCi/g during the last half of 1968; gamma-ray emitters averaged 17.6 and 22.4 pCi/g, respectively, as compared to 7.4 and 8.6 pCi/g for the last half of 1968. Radioactivity in grass samples is presented in table 11.

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Table 11. Radioactivity on vegetation January–June 1969

Radionuclides[a]	Concentration (pCi/g dry weight)			
	Plant perimeter (7 locations)		25-mile radius (7 locations)	
	Maximum	Average	Maximum	Average
Alpha emitters	0.7	0.2	0.6	0.2
Cesium-137	1.2	.8	1.0	.8
Cerium-141, -144	9.4	5.7	10.5	7.1
Ruthenium-103, -106	<1.4	<1.4	1.8	.3
Beryllium-7	14.8	9.8	17.9	12.3
Iodine-131	< .2	< .2	< .2	< .2
Barium-lanthanum-140	<6	<6	<6	<6
Zirconium-niobium-95	2.4	1.3	3.7	1.9

[a] Sensitivity of analysis in pCi/g dry weight; alpha emitters, 0.10; cesium-137, 0.3; cerium-141, -144, 1.0; ruthenium-103, -106, 1.4; beryllium-7 3.0; iodine-131, 0.2; barium-lanthanium-140, 6.0; zirconium-niobium-95, 0.5.

Milk

Milk was sampled at three dairies within a 25-mile radius of the Savannah River Plant (figure 2). Samples, collected biweekly, were analyzed for tritium and radioiodine. Strontium-90 and cesium-137 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during January–June 1969 are shown in table 12.

Average concentrations of the radionuclides in milk were 11 pCi/liter of strontium-90 (compared to 10 pCi/liter of strontium-90 during the last half of 1968) and 13 pCi/liter of cesium-137. Iodine-131 was less than the sensitivity of the analysis (5 pCi/liter) throughout this period. These values are consistent with those reported by the U.S. Public Health Service for most sections of the United States. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level was less than the sensitivity of the analysis, which allows detection of a concentration less than 0.1 percent of the AEC standard for water.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. The January–June 1969 data (shown in table 13) are characteristic of measurements observed at individual stations for the past several years.

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs was, for the most part, too small to be distinguished from natural background radiation or was obscured by fallout from offsite sources. Release of more than the usual amounts of ruthenium-103 in April and curium-244 for a brief period in June caused detection of these radionuclides in air at several points near the plant boundary. The temporary levels were below the respective AEC radiation protection standards. Beta radioactivity in air was about the same as that observed for January–June 1968 and was a twofold increase over the previous 6-month period. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of any radionuclide in river water at Highway 301 did not exceed 0.3 percent of the AEC radiation protection standard.

Table 12. Radioactivity in milk from local dairies, Savannah River Plant January–June 1969

Distributing points	Tritium[a] (nCi/liter)			Strontium-90[b] (pCi/liter)		Cesium-137[c] (pCi/liter)	
	Maximum	Minimum	Average	March	June	March	June
Aiken	5	ND	ND	6	14	6	18
North Augusta	6	ND	ND	11	27	13	22
Waynesboro	11	ND	ND	4	NS	ND	NS
Major distributors[d]	4	ND	ND	5	10	12	16

[a] Sensitivity of analysis—3 nCi/liter. AEC standard—3,000 nCi/liter.
[b] Sensitivity of analysis—1.0 pCi/liter. AEC standard—300 pCi/liter.
[c] Sensitivity of analysis—5.0 pCi/liter. AEC standard—300 pCi/liter.
[d] Milk produced in local dairies, but sold by major distributors.
ND, nondetectable, less than sensitivity of analysis.
NS, no sample.

Table 13. Environmental gamma radiation, Savannah River Plant, January–June 1969

Sampling points	Gamma radiation (mR/day)		
	Maximum	Minimum	Average
Plant perimeter:			
A	0.79	0.13	0.40
B	.41	.18	.34
C	.44	.12	.28
D	.66	.11	.36
E	.42	.15	.22
Average			0.32
25-mile-radius:			
Aiken Airport	.77	.10	.31
Aiken State Park	.32	.13	.22
Allendale	.38	.21	.28
Barnwell	.72	.06	.25
Bush Field	.41	.13	.31
Langley	.59	.03	.27
Sardis	.49	.18	.32
Waynesboro	.74	.14	.29
Williston	.18	.08	.14
Highway 301	.40	.14	.28
Average			0.27

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	January 1969
July–December 1968	November 1969

Reported Nuclear Detonations, April 1970

(Includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission announced that it had conducted two nuclear tests during April 1970.

Both nuclear tests were conducted underground by the Atomic Energy Commission at its Nevada Test Site on April 21, 1970. One was in the low yield range of less than 20 kilotons TNT equivalent, the other in the intermediate yield range (between 20 to 200 kilotons TNT equivalent).

There was some release of gaseous radioactivity from the smaller test. A small amount of radioactivity was detected by the U.S. Public Health Service in the vicinity of Coyote Summit, an unpopulated area on Highway 25 about 10 miles from the boundaries of the government-controlled area.

It was detectable only on sensitive scientific instruments and presented no health hazard. The readings returned to normal background levels in about an hour.

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Errata

In the article "Environmental Survey of Uranium Mill Tailings Pile, Tuba City, Arizona" published in the November 1969 issue of *Radiological Health Data and Reports*, there appeared several errors in tables 6 and 8 on pages 484 and 485.

In table 8 on page 485 change the station 7-radon-222 average from 3.5 to 3.0 pCi/liter.

Table 6. Gross alpha to radium-226 ratios, long-lived airborne particulate activity, Tuba City uranium mill, May 1967

Sample number	Gross alpha (pCi/m³)	Radium-226 (pCi/m³)	Gross alpha/ radium-226
31	.15	.04	3.8
62	.69	.10	6.9
101	.18	.02	9.0
102	.23	.04	5.8

In the January 1970 issue of *Radiological Health Data and Reports*, an error occurred in table 3 of the milk surveillance article on page 17. The iodine-131 12-month average for Portland, Maine, should be 1, and for Baltimore, Md., it should be 0.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

CESIUM–137 CONCENTRATIONS IN ESKIMOS, SPRING 1968. *J. A. Eckert, J. S. Coogan, R. L. Mikkelsen,* and *P. N. Lem. Radiological Health Data Reports, Vol. 11, May 1970,* pp. 219–225.

To determine cesium–137 concentrations, 996 residents of 11 Alaskan villages were whole-body counted during April 1968. The methods of counting and selection of villages were chosen to complement the spring 1967 counts made by Rechen et al. The villages counted in this study were: Ambler, Anaktuvuk Pass Village, Egegik, Kiana, Mekoryuk, Noatak, Noorvik, Selawik, Shishmaref, Shungnak and Teller.

The maximum and average concentrations, considering all villages, were 24.27 nCi/kg and 4.37 nCi/kg, respectively. The average radiation dose index was 34.1 mrad/a. A comparison of the radiation dose indices of individuals counted both in the spring of 1967 and the spring of 1968, indicates that in two villages out of ten there was a significant decrease in the indices.

The inhabitants of villages living on a diet of caribou or moose meat had a higher cesium–137 burden than the inhabitants of villages where reindeer herds supply the main meat source.

The calibration formulas of Rechen and Palmer are compared and it is concluded that earlier studies made by Hanson and Palmer are compatible with the more recent studies made by the U.S. Public Health Service.

KEYWORDS: Alaska, body burdens, cesium–137, Eskimos, radiation dose index, spring 1968.

TRITIUM BODY BURDEN OF CHILDREN, 1967–1968. *A. A. Moghissi* and *Robert Lieberman. Radiological Health Data and Reports, Vol. 11, May 1970,* pp. 227–231.

The tritium concentration in body water of children was determined from samples of urine taken from two children in each of nine Institutional Total Diet Sampling Stations. The tritium concentrations in body water of children gradually decreased from about 1.5 nCi/liter to less than 0.2 nCi/liter during the period, January 1967 to December 1968. Several anomalies were noted.

The dose equivalent from tritium for standard man was calculated to be 0.15 mrem for 1967 and 0.13 mrem for 1968. The dose equivalent for children varies according to age and is roughly 0.1 mrem for a 13-year old child.

KEYWORDS: Body burdens, children, tritium, United States, urine.

TRITIUM CONCENTRATIONS IN FOOD, 1967–1968. *A. A. Moghissi* and *R. J. Lyon. Radiological Health Data and Reports, Vol. 11, May 1970,* pp. 233–236.

Tritium concentrations were determined in food samples obtained from several children's homes in the United States. The average concentrations of tritium in food indicate a decreasing trend from 1967 to 1968. The average dose equivalent from tritium in food was calculated to be 0.08 mrem for 1967 and 0.03 mrem for 1968.

KEYWORDS: Children's diets, food, tritium, United States.

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